CHAPTER 2. PART 29
AIRWORTHINESS STANDARDS
TRANSPORT CATEGORY ROTORCRAFT

SUBPART D - DESIGN AND CONSTRUCTION

DESIGN AND CONSTRUCTION - GENERAL

AC 29.601. § 29.601 DESIGN.

a. Explanation.

(1) This rule requires that no design features or details be used that experience has shown to be hazardous or unreliable.

(2) Further, the rule requires that the suitability of each questionable design detail and part must be established by tests.

b. Procedures.

(1) This rule is met partially by a review of service history of earlier model rotorcraft, or for a new model, review of service experience of models with similar design features. Specifically, this rule covers “features or details” such as the following:

(i) Seat track-to-seat interface fittings should have adequate locking devices to prevent both premature structural failure and premature unlatching.

(ii) Seat belt and harness should be of a type and construction that service experience has shown to be easy to don, unlatch, and remove. They should also be of a type that is reliable, does not interfere with egress, and does not sustain unnecessary wear and tear under normal operations.

(iii) Metallic parts less than a certain thickness gauge and composite materials less than a certain number of plies should not be used. The minimum thickness and number of plies should be based to a large degree on service experience (normal wear and tear) with similar designs.

(2) The effects of service wear on the loading of critical components should be considered. Flight testing, ground testing, and analyses may be used in these considerations.

(3) Tests are required for details and parts which the applicant chooses to use after questions have arisen concerning their suitability.

AC 29.602 § 29.602 CRITICAL PARTS.

a. Explanation. The objective of identifying critical parts is to ensure that critical parts are controlled during design, manufacture, and throughout their service life so that the risk of failure in service is minimized by ensuring that the critical parts maintain the critical characteristics on which certification is based. Many rotorcraft manufacturers already have procedures in place within their companies for handling “critical parts”. These may be required by their dealings with other customers, frequently military (e.g., US DoD, UK MoD, Italian MoD). Although these programs may have slightly different definitions of “critical parts” and have sometimes been called “Flight Safety Parts”, “Critical Parts”, “Vital Parts”, or “Identifiable Parts”, they have in the past been accepted as meeting the intent of this requirement and providing the expected level of safety.

b. Procedures. The rotorcraft manufacturer should establish a Critical Parts Plan. The policies and procedures which constitute that plan should be such as to ensure that-

(1) All critical parts of the rotorcraft are identified by means of a failure assessment and a Critical Parts List is established. The use of the word “could” in paragraph 29.602(a) of the rule means that this failure assessment should consider the effect of flight regime (i.e., forward flight, hover, etc.). The operational environment need not be considered. With respect to this rule, the term “catastrophic” means the inability to conduct an autorotation to a safe landing, without exceptional piloting skills, assuming a suitable landing surface.

(2) Documentation draws the attention of the personnel involved in the design, manufacture, maintenance, inspection, and overhaul of a critical part to the special nature of the part and details the relevant special instructions. For example all drawings, work sheets, inspection documents, etc., could be prominently annotated with the words "Critical Part" or equivalent and the Instructions for Continued Airworthiness and Overhaul Manuals (if applicable) should clearly identify critical parts and include the needed maintenance and overhaul instructions. The documentation should:

(i) Contain comprehensive instructions for the maintenance, inspection and overhaul of critical parts and emphasize the importance of these special procedures;

(ii) Indicate to operators and overhaulers that unauthorized repairs or modifications to critical parts may have hazardous consequences;

(iii) Emphasize the need for careful handling and protection against damage or corrosion during maintenance, overhaul, storage, and transportation and accurate recording and control of service life (if applicable).

(iv) Require notification of the manufacturer of any unusual wear or deterioration of critical parts and the return of affected parts for investigation when appropriate;

(3) To the extent needed for control of critical characteristics, procedures and processes for manufacturing critical parts (including test articles) are defined (for example material source, forging procedures, machining operations and sequence, inspection techniques, and acceptance and rejection criteria). Procedures for changing these manufacturing procedures should also be established.

(4) Any changes to the manufacturing procedures, to the design of a critical part, to the approved operating environment, or to the design loading spectrum are evaluated to establish the effects, if any, on the fatigue evaluation of the part.

(5) Materials review procedures for critical parts (i.e. procedures for determining the disposition of parts having manufacturing errors or material flaws) are in accordance with paragraphs (3) and (4) above.

(6) Critical parts are identified as required, and relevant records relating to the identification are maintained such that it is possible to establish the manufacturing history of the individual parts or batches of parts.

(7) The critical characteristics of critical parts produced in whole or in part by suppliers are maintained.

AC 29.603. § 29.603 (Amendment 29-17) MATERIALS.

a. Explanation. The rule requires that the suitability and durability of materials, the failure of which could adversely affect safety, must be determined by three-fold considerations:

(1) Considerations based on experience or tests.

(2) Meeting approved specifications.

(3) Taking into account environmental conditions such as temperature and humidity.

b. Procedures.

(1) Experience may be used to show a material's resistance to wear and deterioration from environmental effects (environmental effects include both natural environmental effects such as exposure to sunlight, water, salt spray, etc., and installation environmental effects such as exposure to fuel, hydraulic fluids, deicing fluids, etc.). Installation environmental effects should consider both direct exposure contact and expected migration of potentially deleterious fluids and compounds.

Testing for environmental effects may use either coupon testing, full-scale testing, or a combination. A combination of testing and experience may also be used.

(i) MIL-HDBK's-5, -17, and -23 include consideration of some environmental effects and contain reference to additional methods of testing for environmental effects.

(ii) The use of AC 20-107A, Composite Aircraft Structure, is recommended for environmental and damage tolerance considerations of advanced composite materials. (Also see paragraph AC 29 MG 8.)

(iii) The effects of excessive wear and delamination of elastomeric and self-lubricated bearings used in critical load carrying applications in relation to redistribution of loading should be considered.

(2) Where possible, materials that meet widely accepted specifications such as AISI, SAE, MIL, or AMS and alloys which have favorable experience or tests should be used. Where company-developed materials are used, approved specifications are required to ensure the developed properties are duplicated in each lot of material. Raw material quality control is defined in FAA Order N8020-11 which is scheduled to be integrated into a forthcoming advisory circular. Documented specification usage is necessary to maintain quality assurance of materials.

(3) Section 29.613 concerns strength properties and design values. (See paragraph AC 29.613.)

AC 29.605. <u>§ 29.605 (Amendment 29-17) FABRICATION METHODS</u>.

a. <u>Explanation</u>. The basic requirement of this rule is that the methods of fabrication must produce sound structure and produce it consistently.

(1) A process specification is required for fabrication processes requiring <u>close control</u>.

(2) A test program is explicitly required for each new aircraft fabrication method.

b. <u>Procedures</u>.

(1) The approved specifications required by this rule may either be established government/industry specifications such as MIL, AISI, ASTM, or SAE, or the specifications may be company-developed proprietary specifications. Sufficient data should be provided to the FAA/AUTHORITY aircraft engineering offices to show that the desired features are provided by the process specification. In addition, sufficient process controls, inspections, and tests should be coordinated with FAA/AUTHORITY

manufacturing inspection personnel to ensure that continued quality of the process is provided.

(2) In addition to the examples given by the rule; i.e., gluing, spot welding, and heat treating process, specifications should also be prepared for types of welding other than spot welding, for platings of metals, for protective finishes (other than decorative), for sealing, and for unique fabrication methods such as those used for composite materials.

(3) The required test programs should consider static strength effects, fatigue strength effects, and environmental effects as appropriate to the processes.

(4) During the fabrication of advanced composite materials, the effects of fabrication anomalies (i.e., disbonds, voids, porosity) should be considered. Special nondestruct testing inspection techniques and procedures should be developed to cover fabrication with allowable anomalies and permitted repair procedures. (See also paragraph AC 29 MG 8.)

AC 29.607. § 29.607 (Amendment 29-5) FASTENERS.

a. Explanation. Section 29.607 of Amendment 29-5 requires dual locking removable fasteners in critical locations. A nonfriction locking device is specifically required in any bolt subject to rotation, as stated in the rules.

b. Procedures. Advisory Circular 20-71, Dual Locking Devices or Fasteners, December 8, 1970, contains information, procedures, and means of complying with § 29.607 of Amendment 29-5.

AC 29.609. § 29.609 PROTECTION OF STRUCTURE.

a. Explanation. The structure should be suitably protected as specified in the rule to maintain its design strength. Ventilation and drainage provisions must be provided as specified in the rule. Overboard drains should be furnished for corrosive or waste liquids. Drains for flammable fluids are specified in other rules such as §§ 29.999 and 29.1187.

b. Procedures.

(1) The structure may be preserved, painted, or treated with chemical films to protect it from strength deterioration. An approved process specification should be used for these types of treatments.

(2) Parts may be plated or chemically treated, such as anodized, for protection. An evaluation and substantiation may be required to assure the structure or parts are

not adversely affected during, or as a result of, the plating or treatment process. (§ 29.605 concerns approval of process specifications and fabrication methods.)

(3) Plating or material surface hardness or composition changes may require fatigue substantiation to assure the fatigue strength is not altered or is otherwise properly assessed. An approved process specification should be used for these types of treatments.

(4) To prevent water accumulation, drain holes should be placed at possible dams such as bulkheads, and at low points in the fuselage and in the stabilizing surfaces.

(5) Control tubes and tubes used as primary mount structures (i.e., transmission support structure and engine mount structure) should be designed to prevent entry and collection of corrosive fluids or vapor, including water.

(i) A closed insert in each tube end may be used.

(ii) A sealant applied around the tube ends and around each rivet head may be used.

(6) Overboard drains should discharge clear of the entire rotorcraft. Dyed water discharged in flight, may be used to assure fluids are properly drained.

(7) Welded tubes should be flushed and sealed after welding in accordance with an approved process specification.

(8) Refer to AC 43-4, "Corrosion Control for Aircraft," for further procedures.

AC 29.610. § 29.610 (Amendment 29-40) LIGHTNING AND STATIC ELECTRICITY PROTECTION.

a. Background. During the initial development and promulgation of the standards concerning the airworthiness of rotorcraft, it was not necessary to specify design features that would protect the rotorcraft from the meteorological phenomenon of lightning. This was due, in part, to the fact that rotorcraft were primarily operated in a VFR and nonicing environment. Also, a prudent pilot avoided thunderstorms where the possibility of encountering severe weather and a lightning strike was much greater. The construction, design, and operating environment of civil rotorcraft have changed markedly within the past two decades. Many rotorcraft are now authorized to fly IFR in all types of weather environment. One transport design has been approved for flight into known icing conditions. Additionally, many rotorcraft now use the same advanced technologies in structures and systems as do airplanes. Because of these facts, a specific rule on lightning protection of rotorcraft was adopted in Amendment 29-24. For further information, see the preamble of Amendment 29-24 (49 FR 44437; 11/6/84), Proposal 2-14. Section 29.610 is similar to § 25.581 which applies to the protection of structures of transport airplanes. However, the standard provides for specific protection of the aircraft structures as well as the systems of the rotorcraft. In addition, the protection of fuel systems from the effects of lightning is found and referenced in Report DOT/FAA/CT-83/3, the applicable version of Users Manual for AC 20-53, Protection of Airplane Fuel Systems Against Fuel Vapor Ignition Due to Lightning.

b. Explanation.

(1) The regulation requires that the rotorcraft must be protected against the catastrophic effects of lightning. This means that a lightning strike encounter should not prevent the continued safe flight and landing of the rotorcraft.

(2) Paragraph AC 29.1309 addresses the protection required for systems. Protection of the rotorcraft structures may be accomplished in a similar fashion.

(3) The structural components of the rotorcraft should be designed in such a manner that the lightning current may be safely diverted or conducted through the rotorcraft without damaging any critical structure or without causing damage to noncritical structure, the failure of which would preclude the continued safe flight and landing of the rotorcraft. A radome or fin cap which explodes due to a lightning strike and results in catastrophic damage to main or tail rotors is a scenario of lightning damage to a noncritical structure which has catastrophic results.

(4) This type of strike effect on the rotorcraft is generally referred to as direct effects. Direct effects are damage which includes the burning, eroding, blasting, or structural deformation produced by the high currents of the lightning flash passing through the rotorcraft structure.

c. Procedures.

(1) Certification Plan. Although not a regulatory requirement, it is recommended that a formal written certification plan be used to ensure regulatory compliance. The use of this plan is beneficial to both the applicant and the FAA/AUTHORITY because it identifies and defines an acceptable resolution to the critical issues early in the certification process. These are the usual steps to be followed when utilizing a certification plan:

(i) Prepare a certification plan which describes the analytical procedures and/or the qualification tests to be utilized to demonstrate protection effectiveness. Test proposals should describe the rotorcraft and system to be utilized, test drawing(s) as required, the method of installation that simulates the production installation, the lightning zone(s) applicable, the lightning simulation method(s), test voltage or current waveforms to be used, diagnostic methods, and the appropriate schedules and location(s) of proposed test(s).

NOTE: The recommended reference for quantification of the lightning environment, the determination of the aircraft lightning strike zones, and the determination of appropriate test methods is SAE AE4L Committee Report, dated June 20, 1978, Lightning Test Waveforms and Techniques for Aerospace Vehicles and Hardware. Additionally, information may also be found in the NASA publication No. RP-1008, Lightning Protection of Aircraft.

(ii) Obtain FAA/AUTHORITY concurrence that the certification plan is adequate.

(iii) Obtain FAA/AUTHORITY detail part conformity of the test articles and installation conformity of applicable portions of the test setup. Obtain FAA/AUTHORITY approval of the test proposal. A comprehensive test proposal may be used.

(iv) Schedule FAA/AUTHORITY witnessing of the test or tests proposed.

(v) Submit a test report describing all results and obtain FAA/AUTHORITY approval of each report prepared.

(2) Test Conditions. Refer to SAE AE4L Committee Report, dated June 20, 1978, and the NASA publication noted in paragraph c(1)(i) to determine the appropriate test parameters.

(3) Aircraft Design Features and Criteria. MIL-B-5087B, Amendment 2, or later amendment contains valuable information to assist the designer. Figure 6 in the specification contains fault current versus bond resistance information. Refer to the NASA publication noted above also.

(i) Aluminum wire screen or mesh applied to the control or stabilizing surface and electrically bonded at each joint or juncture has been successful in conducting the current without serious damage.

(ii) Metal skin surfaces combined with surface wire screen or mesh have been successful. Also, successful use of surface treatment has been reported. For composites, treatments such as the following have been used: flame spray coatings, aluminized glass, metal foil, metallized fabrics, and conductive paint.

(iii) Ball or roller bearings may be used to conduct the current at rotating joints. However, increased friction or possible seizure of the bearing may occur. The potential for this should be evaluated. Inspection and replacement criteria for possible damage should be addressed in the manual for continued airworthiness. Bearings are especially susceptible to pitting and internal arcing.

(iv) Report DOT/FAA/CT-86/8, April 1987, Determination of Electrical Properties of Grounding, Bonding, and Fastening Techniques for Composite Materials, may assist the applicant.

(4) Fuel Systems. Refer to Report DOT/FAA/CT-83/3 referenced in paragraph AC 29.610a. For additional information on the lightning protection requirements for fuel systems for rotorcraft with a certification basis which includes Amendment 29-26 refer to paragraph AC 29.954.

d. Aircraft Design Criteria for Lightning and Static Electricity Protection.

(1) Lightning Protection.

(i) General. The rotorcraft structure should be provided with means to conduct lightning so that the rotorcraft and its occupants will not be endangered.

(ii) Rotors and Control Systems.

(A) It should be established that an adequate primary bonding path exists between the rotors and the airframe, such that a lightning strike on a rotor will not result in damage to or seizure of gearbox or swashplate bearings, control jacks, etc.

(B) Each hinge and bearing of rotor blades and control surfaces should either-

(1) Be of a type that is capable of withstanding a lightning discharge without damage or seizure leading to loss of function, or

(2) Be provided with at least one primary bonding conductor.

Where bonding conductors are provided, they should be as flexible and short as possible and should be installed so that there is no danger of the conductor jamming the hinge or bearing, particularly if partially disrupted by a lightning strike.

(iii) External Non-metallic Parts.

(A) Where non-metallic parts are fitted externally to the rotorcraft (e.g., rotors, radomes, composite skin panels) and are subjected to lightning, they should be protected against the following risks:

(1) The disruption of the materials because of rapid expansion of gases within them (e.g., water vapor);

(2) The rapid build-up of pressure in voids or in the enclosure provided by the parts resulting in mechanical disruption of the parts themselves or of the structure enclosed by them;

(3) Fire caused by the ignition of the materials themselves or of the materials contained within the enclosures.

(B) Materials used for external non-metallic parts should have low water-absorption characteristics, should not occlude gases, and should be of high dielectric strength in order to encourage surface flashover rather than puncture.

(C) Rotors and other external parts of nonmetallic construction should be provided with effective lightning diverters and/or primary conductors, which are capable of safely carrying lightning discharges, unless it can be shown that damage due to lightning discharge will not endanger the rotorcraft or its occupants. Bonding straps/leads are not required for small gaps between metallic structure and diverters in non-conducting panels in order to comply with the lightning protection criteria. However, an electrical bonding path may be required to achieve static electricity protection.

(D) In some cases (e.g. radomes and rotors), confirmatory tests may be required to check the adequacy of the lightning protection provided.

(2) <u>Characteristics of Lightning Discharges</u>. The data contained in FAA AC 20-53 should be used for the purpose of assessing the adequacy of lightning discharge protection of rotorcraft.

(3) <u>Protection Against the Accumulation of Static Charges</u>.

(i) <u>General</u>. All items, which by the accumulation and discharge of static charges may cause a danger of electrical shock, ignition of flammable vapors or interference with essential equipment (e.g. radio communications and navigational aids) should be adequately bonded to the main aircraft grounding system.

(ii) <u>Intermittent Contact</u>. The design should ensure that random intermittent contact between metallic and/or metallized parts (such as could cause unwanted radio interference or degradation of the components due to sparking) will not occur.

(iii) <u>High Pressure Refueling and Fuel Transfer</u>. Where provision is made for high pressure refueling and/or high rates of fuel transfer, it should be established, by test, or by consultation with the appropriate fuel manufacturers, that dangerously high voltages will not be induced within the fuel system. If compliance with this requirement involves any restriction on the types of fuel to be used or on the use of additives, an appropriate operating limitation should be established under FAR 29.1501(a). The critical refueling rates are related to the rotorcraft refueling installations, and the designer should seek the advice of fuel suppliers on this problem.

(A) With standard refueling equipment and standard aircraft turbine fuels, voltages high enough to cause sparking may be induced between the surface of the fuel and metal parts of the tank at refueling rates above approximately 250 gal/min. These induced voltages may be increased by the presence of additives and contaminants (e.g., anti-corrosion inhibitors, lubricating oil, free water) and by splashing or spraying of the fuel in the tank.

(B) The static charge can be reduced as follows:

(1) By means taken in the refueling equipment such as increasing the diameter of refueling lines and designing filters to give the minimum of electrostatic charging, or

(2) By changing the electrical properties of the fuel by the use of anti-static additives and thus reducing the accumulation of static charge in the tank to a negligible amount.

(4) Primary and Secondary Bonding Paths.

(i) Primary bonding paths are those paths that are required to carry lightning discharge currents. These paths should be of as low an electrical impedance as is practicable. Secondary bonding paths are those paths provided for other forms of bonding.

(ii) Where additional conductors are required to provide or supplement the inherent primary bonding paths provided by the structure or equipment, the cross-sectional area of such primary conductors made from copper should be not less than $3mm^2$ except that, where a single conductor is likely to carry the whole discharge from an isolated section, the cross-sectional area should be not less than $6mm^2$. Aluminum primary conductors should have a cross-sectional area giving an equivalent surge carrying capacity.

(iii) Primary bonding paths should be used for--

(A) Connecting together the main grounding points of separable major components which may carry lightning discharges,

(B) Connecting engines to the main aircraft ground,

(C) Connecting to the main aircraft ground all metal parts presenting a surface on or outside of the external surface of the rotorcraft, and

(D) Conductors and lightning diverters on external non-metallic parts.

(iv) Where additional conductors are required to provide or supplement the inherent secondary bonding paths provided by the structure or equipment, the cross-sectional area of such secondary conductors made from copper should be not less than $1mm^2$.

(5) Resistance and Continuity Measurements. Measurements should be made to determine the efficacy of the bonding and connection between at least the following:

(i) Primary Bonding Paths

(A) The extremities of the fixed portions of the rotorcraft and such fixed external panels and components where the method of construction and/or assembly leads to doubt as to the repeatability of the bond, e.g., removable panels.

(B) The engines and the main aircraft ground.

(C) External movable metal surfaces or components and the main aircraft ground.

(D) The bonding conductors of external non-metallic parts and the main aircraft ground.

(E) Internal components for which a primary bond is specified and the main aircraft ground.

(ii) Secondary Bonding Paths.

(A) Metallic parts, normally in contact with flammable fluids, and the main aircraft ground.

(B) Isolated conducting parts subject to appreciable electrostatic charging and the main aircraft ground.

(C) Electrical panels and other equipment accessible to the occupants of the rotorcraft and the main aircraft ground.

(D) Grounding connections that normally carry the main electrical supply and the main electrical return. The test on these connections should be such as to ensure that the connections can carry, without risk of fire or damage to the bond, or excessive volt drop, such continuous normal currents and intermittent fault currents as are applicable.

(E) Electrical and electronic equipment and the main earth, where applicable, and as specified by the rotorcraft manufacturer.

(F) Static dischargers and the main rotorcraft structure.

AC 29.611. § 29.611 INSPECTION PROVISIONS.

a. Explanation. The rotorcraft must have access panels, or openings, that will allow for proper maintenance and/or adjustment of the rotorcraft systems.

(1) The rule states: There must be means to allow close examination of each part that requires recurring inspection, adjustment for proper alignment and functioning, or lubrication.

(2) "Structural" or load-carrying access panels may be used to comply with the rule. Structural panels should have stencils or permanent labels (§ 29.1541(a)(2)) stating the panels must be installed prior to ground or flight operation.

(3) Holes or "nonstructural" access panels should be used whenever possible.

b. Procedures.

(1) The determination of compliance can be accomplished in conjunction with the following activities:

(i) Reviewing type design drawings.

(ii) Conformity inspections accomplished during certification testing.

(iii) Be evaluated during the control system proof and operation tests (§§ 29.681 and 29.683).

(iv) During type inspection tests and functioning and reliability testing.

(2) Equipment requiring frequent inspections (at less than 25-hour intervals), lubrication, or adjustments should be accessible through "nonstructural" doors. Areas or items requiring daily attention should be accessible through "nonstructural" doors since properly rated maintenance personnel are required to "open and close," or reinstall structural panels and special design features, such as multiple pins and latches, are generally necessary for structural doors.

(3) If the rotorcraft is subject to an FAA Maintenance Review Board Approval Program, further review of the rotorcraft inspection provisions will be obtained.

AC 29.613. § 29.613 (Amendment 29-17) MATERIAL STRENGTH PROPERTIES AND DESIGN VALUES.

a. Explanation. The rule requires the use of materials that have a known minimum strength value. The structure must not be understrength and must be designed to minimize fatigue failure.

(1) Material design values in certain specified documents may be used. The FAA/AUTHORITY may approve other material design values thus allowing the applicant greater flexibility in selection of materials by proving their strength properties and design values as stated in § 29.613(d).

(2) Other materials that may be new or are not included in the specified documents may be tested and design values established as provided by § 29.613(a) and (d).

(3) Section 29.613(d) requires the selection of materials that will retain design values and properties in the type of service environment and for the length of service time intended for the structure.

(4) Section 29.613(c) is an objective rule concerning minimizing fatigue failures. Paragraph AC 29.571, § 29.571, concerns quantitative fatigue substantiation requirements.

b. Procedures.

(1) The properties and design values in the documents noted in the rule may be used.

(2) MIL-HDBK-5, Metallic Materials and Elements for Flight Vehicle Structure, Chapter 9, contains procedures for establishing design values of additional materials. Uniform means of presenting the data is also contained in this chapter.

(3) Design values and properties must include effects of the service environment and service time. An example is exposure at elevated temperatures on the ultimate tensile strength of 7079-T6 aluminum alloys as found in figure 3.7.4.1.1(c) of MIL-HDBK-5C.

(4) The probability of disastrous fatigue failures must be minimized. This may be accomplished by using design features usually identified as fail-safe features, such as the following, which were obtained from Advisory Circular 20-95. See paragraph AC 29.571 for the fatigue requirement information.

(i) Selection of materials and stress levels that provide a controlled slow rate of crack propagation combined with high residual strength after initiation of cracks (lightly loaded structures).

(ii) Use of multipath construction and the provision of crack stoppers to limit the growth of cracks.

(iii) Use of composite (multielement) duplicate structures so that a fatigue crack or failure occurring in one element of the composite (multielement) member will be confined to that element and the remaining structure will still possess adequate load-carrying ability.

(iv) Use of backup structure wherein one member carries all the load, with a second member available and capable of assuming the extra load if the primary member fails.

(v) Design to permit detection of cracks including the use of crack detection systems, in all critical structural elements before the cracks can become dangerous or result in appreciable strength loss, and to permit replacement or repair.

(5) Acceptable standards for pressurized containers or cylinders, such as cylinders of nitrogen, used to inflate emergency floats may be found in 49 CFR 178 Subpart C, §§ 178.36 through 178.68. Specifically, § 178.44 concerns standards for steel cylinders used in aircraft that are subjected to at least 900 PSI service pressure. This standard includes strength, test, material property, inspection, quality, design features, identification and inspection report requirements. As an example, § 178.44-14, entitled "Hydrostatic Test," requires that each cylinder must be (proof) tested to at least 5/3 times the service pressure. Section 178.44-16, entitled "Burst Test," also states that one cylinder taken at random out of each lot of cylinders shall be hydrostatically tested to destruction.

(6) Other design criteria may be developed and approved under the provisions of FAR Part 29 as a unique part of the aircraft type design.

AC 29.613A. <u>§ 29.613 (Amendment 29-30) MATERIAL STRENGTH PROPERTIES AND DESIGN VALUES</u>.

a. <u>Explanation</u>. Amendment 29-30 added explicit probability standards criteria to § 29.613(b). This amendment also provided for testing or proving the strength of selected individual items rather than conducting coupon tests to develop generic material strength properties that would be used for design purposes.

b. <u>Procedures</u>. The basic procedures of paragraph AC 29.613 still apply, except:

(1) Probability criteria common with MIL-HDBK-5D are explicitly allowed to determine strengths for metallic materials whose data are not available in MIL-HDBK-5D. These specific probability criteria should be used in conjunction with MIL-HDBK-17B whenever determining material strength properties for non-metallics. (Also, reference paragraph AC 29 MG 8.)

(2) New § 29.613(e) provides for the premium selection of materials. The premium selection of materials method uses a specimen from each individual item (part) to determine its properties before its use is allowed. This is a highly specialized and possibly costly method which applies only to parts that have areas available from which specimens can be obtained without destroying the part. The rotorcraft type design data of those parts made from premium selection should have the necessary information, such as minimum allowable strength, on the part drawing.

AC 29.619. <u>§ 29.619 SPECIAL FACTORS</u>.

a. <u>Explanation</u>.

(1) This is a general rule to complement other rules. Special factors are employed for reasons cited in the rule to ensure an airworthy aircraft structure. The 1.5 ultimate load factor in § 29.303 is multiplied by a special factor as specified in the rule.

(2) Specific factors are prescribed for castings and fittings in §§ 29.621 and 29.625 respectively. Factors may be prescribed for bearings with free clearance as stated in § 29.623. In addition, any other factor may be prescribed "to ensure that the probability of the part being understrength because of the uncertainties specified in § 29.619(a) "is extremely remote."

b. <u>Procedures</u>.

(1) One example of fitting factor use follows:

1,000 pounds limit design load x 1.15 fitting factor x 1.5 ultimate load factor equals 1,725 pounds ultimate design load.

(2) Other specific factors may be similarly applied. Refer to §§ 29.623, 29.625, 29.685, and 29.785.

(3) Other factors may be imposed as cited in the rule. Advisory Circular 20-107, paragraphs 5 and 6, are examples of requiring tests of component and subcomponent structure to account for variability of strength and stiffness of composite structures. Factors appropriate for the particular design are obtained and used in substantiation of the composite structure.

(4) The rule complements §§ 29.603 and 29.613. Regardless of the rule invoked, the variability of the material and/or assembly properties must be accounted for.

(5) Ground resonance can occur due to flexibility in the rotor pylon restraint system as well as with landing gear flexibilities. This evaluation should include variations in stiffness and damping of the rotor pylon restraints that may occur in service (reference "Ground Vibrations of Helicopters," M.L. Deutsch, JAS, Vol. 13, No. 5, May 1946).

AC 29.621. <u>§ 29.621 CASTING FACTORS</u>.

a. <u>Explanation</u>. Casting design, test, and inspection criteria are included in this rule for critical and noncritical structural castings. Hydraulic or other fluid containers are not subjected to “structural loads” but are subject to pressure testing as a part of hydraulic or other flight systems. Critical and noncritical castings are defined in the rule.

(1) Factors, tests, and inspections are specified for structural castings. Additional factors, tests, and inspections may be applied, as prescribed by §§ 29.603, 29.605, or 29.613, for foundry quality control.

(2) For castings that have surfaces subject to bearing structural design loads, the casting factor need not exceed 1.25 with respect to bearing stresses and need not be used with respect to the bearing surfaces if the bearing factor of § 29.623 exceeds the applicable casting factor.

(3) Critical castings must have a casting factor not less than 1.25 and must receive 100 percent inspection as specified including radiographic inspection. Static test requirements are also specified in addition to the inspection requirements.

(4) Noncritical structural castings may have a casting factor as small as 1.0 with attendant increased inspection and quality control requirements. Use of larger casting factors reduces the inspection and quality control requirements.

(5) Structural static and fatigue substantiation, by test or analysis, are still required in addition to any casting static tests required by this rule.

b. Procedures.

(1) The rotorcraft castings should be classified as critical, or noncritical, or nonstructural, or fluid container as soon as possible in the certification program. The applicant should then be prepared to propose the tests required for certification.

(2) The casting factors and associated inspection requirements dictated by § 29.621(c) and (d) are shown below:

INSPECTION REQUIREMENTS

	CRITICAL CASTINGS <(2)>		NONCRITICAL CASTINGS <(3)>	
CASTING FACTOR RANGE <(1)>	FAA REQUIRE-MENT 29.621(c)	OTHER CLASSIFICATION	FAA REQUIRE-MENT 29.621(d)	OTHER CLASSIFICATION
2.01 OR GREATER	<(7)>		<(4)>	
1.50 TO 2.00	<(7)>		<(5)>	
1.250 TO 1.499	<(7)> <(8)>		<(6)>	
1.00 TO 1.249	NOT ALLOWED	NOT ALLOWED	<(7)> <(8)> <(9)>	

<(1)> Ultimate load = Casting factor x 1.5 x limit load. CAUTION: For casting factor range of 1.25 to 1.5 see yield test requirements of NOTE <(8)>. The mechanical properties to be used for analysis shall be based on the tabulated values of MIL-HDBK-5 or other approved sources, reference § 29.613.

<(2)> Critical castings are those castings whose failure would preclude continued safe flight and landing or result in injury to any occupant, reference § 29.621(c).

<(3)> Noncritical castings are castings other than those defined by NOTE <(2)>.

<(4)> Each casting shall receive 100 percent visual inspection.

<(5)> Each casting shall receive 100 percent visual and reduced magnetic particle or penetrant inspection or approved equivalent methods.

<(6)> Each casting shall receive 100 percent visual and reduced radiographic and magnetic particle or penetrant inspection, or approved equivalent methods.

<(7)> Each casting shall receive 100 percent inspection by visual, radiographic and magnetic particle or penetrant inspections or approved equivalent methods.

<(8)> Three sample castings shall be static tested and shown to meet:

No failure at 1.25 x 1.5 x limit load, and
No yielding at 1.15 x limit load.

<(9)> Castings shall be procured to a specification that guarantees the mechanical properties of the material in the casting and provides demonstration of these properties by test of coupons cut from the castings on a sampling basis.

This chart may be included in the casting test proposal report. It is recommended that the applicant include in the test proposal report additional information such as shown in paragraph AC 29.621b(3).

(3) The casting test report may include the following sections or items in a Part I of the report. The report may also have a Part II that contains the test results as shown in the following example report. The following sections are a recommended format content of the report. Appropriate changes should be made as desired to accommodate the applicant's system.

EXAMPLE OF REPORT
INTRODUCTION

This report presents the proposal for the static test of the castings used on the Model XYZ. The castings will be tested in compliance with Federal Aviation Regulations, Part 29, § 29.621. The purpose of this test is to substantiate the structural strength of the castings used on the Model XYZ. Part II of this report, which will be published after static tests have been completed, will present test results.

All test specimens will be selected as radiographic standards of acceptance for the particular castings (see Test Specimen). Additional information on selecting the specific castings may be included in the test specimen section of this report.

Load sheets giving direction and magnitude of loads for each of the castings are presented in numerical order by part number at the end of this report. The test loads and design criteria for the castings are discussed in detail in the test loads section of this report.

The test loads will be applied and reacted using mating aircraft parts or special fixtures which simulate the mating parts. The methods and apparatus to be used for the static tests of the castings are discussed in the apparatus and method section of this report.

Testing will be conducted in…(location).

TEST SPECIMEN

The castings which will be tested are listed in numerical order in figure AC 29.621-2. Those castings which, after structural analysis, show less than a 1.5 casting factor will be tested. All directions are given with reference to a forward facing position in the rotorcraft.

On the basis of a radiographic examination, the three castings which are of the poorest acceptable quality in the first production lot of castings will be selected as test specimens. The poorest of the three castings will be selected as the initial test casting and its radiograph or ASTM standard will be used as the standard for accepting future castings of the particular part unless later standards are approved. Three castings must be tested for each critical condition for each part.

Conformity Inspection

Each machined casting will be subjected to an FAA/AUTHORITY conformity inspection prior to testing to determine compliance with the type design drawings. A conformity report for each casting may be incorporated in Part II, Test Results, of this report.

The test specimen will be permanently marked or defaced after testing to preclude its use on a rotorcraft.

See figure AC 29.621-2 for an example of a convenient means of listing castings.

TEST LOAD

The test load(s) to be applied to each casting represents the critical loading condition(s) for that casting. The critical conditions on each of the castings were determined by the design criteria and substantiating data approved by the FAA/AUTHORITY.

The design criteria for all of the castings to be static tested may fall into one of two categories. The load factors and structural acceptability requirements for each category are discussed below. Casting factors that are included on the load sheets of each part do not apply in the discussion below. (See paragraph AC 29.621b(2) for casting factors.)

Castings Designed to Limit Load Conditions

A structural analysis of each test casting showing the critical design limit load conditions is given in the data, (reference report number here). The load factors for the static test of the castings are as follows:

1.15 x design limit load = design yield load
1.50 x design limit load = design ultimate load

Castings Designed Only to Crash Landing Conditions

The castings in this category were designed using a crash landing load factor for the design ultimate load. The design yield load criteria of 1.15 x limit load need not apply to these castings. The test loads for these castings may be given in terms of design ultimate load on the individual casting load sheets shown in Part I of this report.

Test Procedures

Depending on the results of the initial static test of each casting, the following procedure will be used.

a. If in the initial test of critical castings the casting is found to have a casting factor of 1.5 (1.5 x design ultimate load), the casting will be considered acceptable and no further tests will be conducted.

b. If in the initial test(s) the critical casting is found to have a casting factor less than 1.5 but equal to or greater than 1.25, two additional castings will be tested for each critical load condition. Each must also show a minimum casting factor of 1.25.

c. If in the initial test, or in one of two additional tests, a casting shows a casting factor less than 1.25 times design ultimate or yields prior to reaching 1.15 times design limit load, the casting will be redesigned and retested. The yield criteria are also applicable to the first two procedures with the exception of critical castings designed to crash landing conditions.

TEST APPARATUS AND METHOD

The Model XYZ casting static tests will be conducted using fixtures designed to simulate the installation of the castings in the aircraft. Where practical, mating aircraft parts will be used to apply and react test loads. When practical, the static tests will be conducted with mating castings assembled when the critical loads for the mating castings are compatible; otherwise, fixtures simulating the mating parts may be designed and fabricated for the tests. Assembly hardware used to mount test castings will be the same as hardware used on the rotorcraft. All bolt torques and other assembly notes will conform to the type design assembly instructions.

The tests will be conducted using calibrated load measuring devices such as hydraulic cylinders and pressure gages, load cells, strain gage bridges, or dead weights.

Deflections of the casting may be measured using graduated dial indicators or scales in all tests. The deflection indicators will be based or mounted on the casting and will measure casting deflection only, when possible, otherwise the indicators will be based on the fixture and measure deflection of the casting relative to the fixture. Deflection readings will be made at 20 percent increments of limit load through 100 percent of limit load and at 115 percent of limit load. These increments may be changed if necessary. Permanent deformation readings will be made after relieving 115 percent and 150 percent of limit load.

See figure AC 29.621-1 as an example of a load sheet.

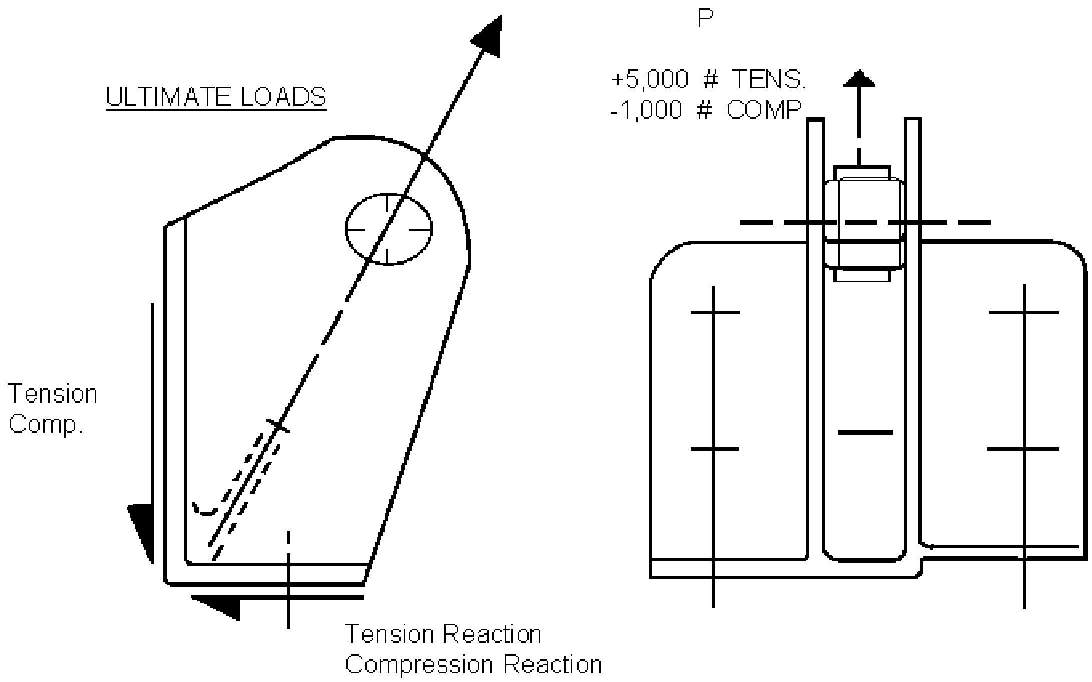

FIGURE AC 29.621-1
EXAMPLE OF CASTING LOAD SHEET
RETRACT ACTUATOR SUPPORT - LANDING GEAR

Include spherical bearing with clamped-up bolt and a link in the test setup to confirm the stability. Loads are based on a jam condition with actuator operating at 1,700 PSI pressure maximum.

A 1.25 casting factor is included in these loads.

These loads were derived from data in approved structural loads and analysis report.

END OF SAMPLE REPORT

(4) The format of the previous guidance material may be changed to accommodate the applicant's method of data presentation.

(5) Nonstructural castings may be tested and included in the test report.

(6) Cast fluid containers, including hydraulic fluid containers, may be tested as prescribed in other rules of FAR Part 29 and a test proposal and test results report may be included in the casting test report or an appropriate report may be referenced for convenience. We recommend use of one report to contain test data or reference to test data for all castings used on the rotorcraft.

FIGURE AC 29.621-2 EXAMPLE

CASTINGS TO BE STATIC TESTED FOR MODEL XYZ

CASTING NO.	MACHINE OR ASSY. NO.	NAME AND LOCATION	MATERIAL	REF. LOAD SHEET FIG. NO.
		Base Assembly, Pilot's Collective Column		

AC 29.623. § 29.623 BEARING FACTORS.

a. Explanation.

(1) The rule requires use of a minimum bearing factor in free fit joints to account for effects of typical relative motion. A minimum value is not specified in the rule. The factor, appropriate for the application, is applied to the ultimate bearing strength of the softest material used as a bearing. A definition of free fit (clearance fit) is noted in Subparagraph b(7) below.

(2) Specific bearing factors are specified by § 29.685(e) for control system joints subject to angular rotation. These factors are applied to the ultimate bearing strength of the softest material used as a bearing in the control system. Control systems ball, roller, or needle bearings are covered by § 29.685(f).

(3) MIL-HDBK-5C, paragraph 8.3, refers to design standards for plain or journal bearings or bushings. These standards are found in Air Force Systems Command Design Handbook 2-1, Airframe, Chapters 2 and 6.

b. Procedures.

(1) Control system joint bearings are discussed under paragraph AC 29.685, § 29.685 of this document but the bearing factors are noted here for convenience. Section 29.685(e) requires a 2.0 bearing factor for cable systems and a 3.33 bearing factor for push-pull systems other than ball and roller bearing systems. The manufacturer's static, non-Brinell rating of ball and roller bearings may not be exceeded as stated in § 29.685(f).

(2) A landing gear pivot, grease lubricated, plain bearing is one example of a free fit subject to pounding or vibration. A bearing factor of 2.0 may be used or another factor may be proven for grease lubricated plain bearing or bushing to account for the anticipated higher loads caused by pounding or vibration. See subparagraph AC 29.623b(6) for ball or roller bearings.

(3) A typical engine mount bolt installation with a plain bearing having a free or loose fit (not interference fit), is another example of a sleeve bearing application subject to a design bearing factor. As an example, a bearing factor of 1.85 may be applied to the design loads on the softest material reacting the bearing loads. A different factor will be acceptable if proven. For example, the design limit load may be calculated for a .312-inch-diameter bolt in a 2-inch-long bearing. The bearing projected area is .312 x 2 = .624-inch-square. The design limit load is 3,000 pounds. The design limit bearing stress is 3,000 pounds/.624-inch-square x 1.85 = 8,894 PSI. If a free or loose fit is not used; i.e., tighter than free fit, a bearing factor is not required.

(4) Military standard part specification, MS 21240, "Bearing, Sleeve Plain, TFE Lined" and MS 21241, "Flanged Bearing, Sleeve Plain, TFE Lined contain allowable

load ratings, static, and dynamic that apply to the particular use of the bearing. An appropriate bearing factor should be applied to the static rating. Military Specification MIL-B-8943A, Amendment 3, “Bearing, Sleeve, Plain, and Flanged, TFE Lined” (temperature range -65° F to 250° F) shows that MS 21240 and MS 21241 sleeve bearings have been superseded by MS 1934/1 and MS 81934/2 sleeve bearings, respectively. Military Specification MIL-B-81934, Amendment 2, “Bearings, Sleeve, Plain and Flanged, Self-Lubricating,” uses TFE liners. These bearings are intended for use in a temperature range from -65° F to +325° F. Whenever a sleeve bearing is used an appropriate bearing factor should be applied to the static rating that is contained in the specification or standard. Other sleeve bearings are contained in standards NAS 72 through NAS 77, NAS 537, and NAS 538. The installation design information is only contained in standards NAS 72 through NAS 74. These types of plain sleeve bearings are designed for clamping to the shaft or bolt with relative motion occurring on the bearing outside diameter. An appropriate bearing factor is required for the application.

(5) The minimum fitting factor 1.15, specified by § 29.625, must be applied as specified to account for load distribution at the fitting. This fitting factor need not apply to plain or journal “bearings” whose “bearing factor” exceeds 1.15.

(6) For airframe and landing gear structural joints, the manufacturer’s static, non-Brinell rating of ball and roller bearings may not be exceeded. ABEC Class 1 bearings or better quality bearings may be used in airframe structural joints and landing gear; ABEC Class 3, 5, or 7 bearings should be used in rotor pivot joints. The non-Brinell rating includes consideration of the bearing factor and no other bearing factor is required.

(7) A free fit was described in American Standards Association (ASA) Standard B4a-1925. The “free fit” clearances and tolerances of this old standard are now called Class RC6, Medium Running Fit, in ASA Standard B4.1, 1955. As an illustration using these standards, a 1-inch diameter shaft and a plain sleeve bearing would have a clearance ranging from .0014 to .0040 inch.

AC 29.625. <u>§ 29.625 FITTING FACTORS</u>.

a. <u>Explanation</u>. A 1.15 factor is specified to assure that the calculated load and stress distribution within any fitting is conservative. Application of the factor is excluded or excepted as stated in the rule.

b. <u>Procedures</u>.

(1) The factor may be applied to the calculated load or stress for the fitting.

(2) The structural substantiating data for the rotorcraft, including the rotor system, must include the prescribed fitting factor. The rotor system includes the flight control system rotor head and hubs and rotor blade attachments.

AC 29.629. § 29.629 FLUTTER.

a. Explanation.

(1) The rotorcraft must be free from flutter.

(2) Section 29.251 vibration is an associated flight requirement concerning flight demonstrations. See paragraph AC 29.251 for this standard.

(3) Section 29.571(a)(3) concerns in-flight measurement of loads or stresses.

b. Procedures.

(1) Freedom from flutter may be shown by analysis or appropriately instrumented flight flutter tests.

(2) The flight loads survey proposal submitted for compliance with § 29.571 may also contain tests to fulfill compliance with § 29.629. The flight loads survey program encompasses the envelope of design airspeed and rotor RPM, and sufficient aerodynamic excitation is generally present to excite any latent flutter modes.

(3) Flight loads survey data or flight flutter test data submitted should be reviewed to assure that excessive oscillatory loads of rotors or surfaces will not be encountered.

AC 29.629A. § 29.629 (Amendment 29-40) FLUTTER AND DIVERGENCE.

a. Explanation. Amendment 29-40 adds the requirement that each aerodynamic surface of the rotorcraft must be free from divergence in addition to the requirement of freedom from flutter. The aeroelastic stability evaluations required by this regulation include flutter and divergence. Compliance with this regulatory requirement should be shown by analysis and/or flight test, supported by any other means found necessary by the Administrator. The aeroelastic evaluation of the rotorcraft should include an investigation of the significant elastic, inertia and aerodynamic forces on all aerodynamic surfaces (including rotor blades) and their supporting structure. The forces associated with the rotations and displacements of the plane of the rotors should be considered.

b. Procedures.

(1) It should be shown by analysis that the rotorcraft is free from flutter and divergence (unstable structural distortion due to aerodynamic loading) under any condition of operation including:

(i) Airspeeds up to 1.11 V_{NE} (power on and power off).

(ii) Main rotor speeds from 0.95 x the minimum permitted speed up to 1.05 x the maximum permitted speed (power on and power off).

(iii) The critical combinations of weight, CG position, load factor and altitude.

(2) Adequate tolerances should be established on those physical quantities which could affect flutter, divergence, or structural distortion to a degree sufficient to cause a significant deterioration in the characteristics of the rotorcraft, such that likely variations in these quantities will not result in flutter or divergence within this envelope.

(3) All physical properties which could contribute to a reduction in the predicted flutter or divergence margins are to be investigated, including stiffness, damping, mass balance, and aerodynamic coefficients. Parametric variations should be sufficient to cover any possible variation due to manufacturing and maintenance tolerances and environmental factors, and to provide conservatism where estimated values are used. Linear approximations to non-linear variations may be used.

(4) Where approval for flight in icing conditions is being sought, the effects of ice accretion on unprotected surfaces, including that which might occur as a result of a single system malfunction, should be considered.

(5) Rotorcraft should be demonstrated by suitably instrumented flight tests to be free from flutter and divergence at all combinations of forward speed and rotor RPM (power off and power on), up to 1.11 V_{NE} and 1.05 times the maximum permitted RPM (except that combinations of speed in excess of V_{NE} and rotor speed in excess of the maximum permitted are not required to be tested). Flight tests to demonstrate compliance with flutter and divergence requirements may normally be addressed simultaneously with testing in compliance with §§ 29.251, 29.571, 29.1505 and similar regulations. Special flight tests for flutter and divergence would not normally be required.

(6) Stabilizing surfaces may be addressed by analysis alone if flutter and divergence margins can be shown to provide adequate conservatism. Flight testing at 1.05 times the maximum power-on rotor speed may also be waived if it is considered impractical, and can be adequately addressed by analysis.

AC 29.631. § 29.631 (Amendment 29-40) BIRD STRIKE.

a. Explanation. Amendment 40 adds requirements for continued safe flight and landing after a bird strike. Compliance with § 29.631 should be shown for a 2.2 lb (1.0 kg) bird at a relative velocity equal to the lesser of V_{NE} or V_H at altitudes up to 8,000 feet. For Category A certification, the rotorcraft should be capable of continued safe flight and landing after the described bird strike. For Category B certification, the rotorcraft should be capable of a safe landing after the bird strike.

b. Procedures. For compliance with FAR 29.631, it should be demonstrated by test or analysis supported by test evidence that,

(1) The windshields will withstand, without penetration, and,

(2) The rotorcraft is capable of continued safe flight and landing following impact with a 2.2-lb (1.0 kg) bird at V_{NE} or V_H (whichever is the lesser) at altitudes up to 8,000 feet.

SUBPART D - DESIGN AND CONSTRUCTION

ROTORS

AC 29.653. § 29.653 (Amendment 29-3) PRESSURE VENTING AND DRAINAGE OF ROTOR BLADES.

a. Explanation. The rule requires each rotor blade to be provided with venting and drainage means (i.e., holes, etc.) or the blade must be sealed and designed to withstand internal pressure.

b. Procedures. Although the rule provides for venting and drainage features, recently certificated blades have been designed to be sealed and to sustain the "maximum pressure differentials expected in service." For modern blade designs, the internal pressure buildup due to environmental effects and centrifugal acceleration effects (near the tip) can be readily sustained with moisture sealing accomplished. The use of sealed blades is highly advantageous and recommended because of the possibility for severe corrosion damage resulting from trapped moisture and because of the difficulty in finding internal corrosion damage by use of field level inspections.

AC 29.659. § 29.659 (Amendment 29-3) MASS BALANCE.

a. Explanation. The rule requires that mass balancing of rotors and blades be provided, as necessary, to prevent excessive vibration and flutter. Further, the rule requires structural substantiation of the mass balance installation.

b. Procedures.

(1) The weight, geometry, and location of rotor and blade mass balance devices are determined as the requirements of §§ 29.571 and 29.629 are met.

(2) The structural substantiation should show static strength to meet the maneuver and gust loads of §§ 29.337, 29.339, and 29.341. In addition, the main rotor loads of § 29.547(c) should be substantiated. The fatigue strength of the mass balance devices (including structural supports) should meet the requirements of § 29.571.

(3) In addition to the appropriate strength requirements, some recent designs have included features which trap the balance weight inside a limited area even if the primary attachment means (adhesive, bolts, etc.) fail. This type of design feature is recommended because of the severe loading environment to which balance devices are subjected.

AC 29.661 § 29.661 (through Amendment 29-3) ROTOR BLADE CLEARANCE.

a. Explanation.

(1) This paragraph discusses the regulatory requirement contained in § 29.661. That requirement is that there must be enough clearance between the rotor blades (main and tail rotor blades) and other parts of the structure to prevent the blades from striking any part of the structure during any operating condition.

(2) In the past, some rotorcraft that have been shown to comply with § 29.661 during the certification process have experienced subsequent accidents involving in-flight contact between the main rotor and airframe (rotor/airframe contact). Completion of developmental and TIA flight testing without a rotor/airframe contact incident has proven not to be adequate demonstration of compliance with § 29.661 in all cases.

(3) Historically, in-flight rotor/airframe contact accidents have occurred as a result of mast bumping, rotor stall, or excessive rotor flapping due to control manipulation. For some rotorcraft, a more thorough examination may be required to ensure adequate clearances.

b. Procedures. Testing should be conducted by the applicant, prior to FAA/AUTHORITY participation, to ensure that the rotorcraft is in compliance with § 29.661 in all areas of the envelope during all operational maneuvers expected throughout the life of the aircraft. The tests should be performed concurrently with performance, flight characteristics, and flight loads testing. Tests should include:

(1) A blade flapping survey to determine flapping angles/margins, blade bending, and blade clearance from the entire airframe. Data may be gathered from instrumented flapping hinges, instrumented blades, high-speed video from airframe mounted cameras, a chase aircraft, or other acceptable means.

(2) Determine that margin exists between the minimum rotor RPM encountered during testing for compliance with § 29.143(d) and the RPM (power off) at which analysis shows that the rotor will experience a significant stall. A significant stall condition may be defined by the rotor reaching an RPM from which normal operating RPM is unrecoverable due to drag on the main rotor blades or, a stall that results in excessive main rotor flapping. The rotor RPM decay rate under the critical conditions of weight, density altitude, minimum approved power-on rotor RPM must provide a margin between the minimum rotor speed achieved during demonstration of compliance with §§ 29.87 and 29.143(d) and the analytically derived rotor stall RPM for the same conditions. For example, the minimum rotor RPM resulting during H-V tests must allow for a margin above the rotor stall value to allow for variations that may occur during operational flying.

(3) During parts of the certification flight test program, frangible devices (wood dowels) or other means of measuring clearance, may be requested to confirm that the clearances shown in the drawings and verified during company flight tests are adequate in all operating conditions. Balsa wood dowels or styrofoam pads may be clamped to the aft part of the fuselage and cabin roof within the rotor arc. Such devices may be

especially helpful in determining clearance during autorotation and controllability testing under FAR 29.143. If such measuring devices are used, the type inspection report should contain a record of clearance found during the tests. During TIA flight testing, it is not necessary to precisely determine the clearance but only necessary to determine "enough clearance" as stated in the rule.

AC 29.663. § 29.663 GROUND RESONANCE PREVENTION MEANS.

a. Explanation.

(1) This section, adopted in Amendment 29-3, and amended by Amendment 29-30, requires reliability and damping action investigation for the ground resonance prevention means which typically includes the shock struts. Section 29.1529 requires associated maintenance information in the maintenance manual. The probable range of variations in service, not just the allowable range, should be established and investigated as prescribed. This probable range includes operation on the ground, or other appropriate landing surface applicable to the rotorcraft design. Quantitative test data are generally obtained in compliance with this rule although analysis or tests may be employed. The preamble to Amendment 29-3 contains additional information.

(2) Note that the maintenance information is not contained in the approved mandatory section of the maintenance manual.

(3) Paragraph AC 29.241 concerns demonstrating freedom from ground resonance during certain applicant and TIA verification evaluations or tests of the rotorcraft. Section 29.241 complements the requirements of § 29.663. As noted in paragraph AC 29.241, a specific requirement for a ground vibration survey was removed from CAR Part 7. However, § 29.663 was adopted by Amendment 29-3 to investigate possible sources of ground resonance and to assure that the reliability of the ground resonance prevention means; i.e., dampers, shock struts, etc., would preclude the occurrence of ground resonance. The total rotorcraft system, including landing gear, struts, tires, etc., is evaluated under this standard.

(4) Viscous dampers in the rotor head have been used for many years to prevent ground resonance. Modern rotorcraft designs may also use elastomeric dampers and may use elastomeric bearings in the rotor head and rotor pylon attachment to the airframe. The standard applies to viscous and elastomeric dampers. The “probable” range in damping shall be investigated. The standard also requires investigation of the probable range of variations of these dampers, whether viscous or elastomeric, and elastomeric bearings to preclude ground resonance.

(5) Ground resonance can occur due to flexibility in the rotor pylon restraint system as well as with landing gear flexibilities and/or shock struts. See paragraph AC 29.663b(2) for an explanation. An analysis may be done to show the effect of the rotor pylon mount stiffness on ground resonance stability. If the analysis

shows that rotor pylon mount stiffness could affect ground resonance, the evaluation should include variations in stiffness and damping of the rotor pylon restraints that may occur in service (reference “Ground Vibrations of Helicopters,” M.L.. Deutsch, JAS, Vol. 13, No. 5, May 1946).

b. Procedures.

(1) The reliability of the means for preventing ground resonance may be substantiated as stated in the standard. An analysis report or a test proposal and subsequent test report may be used to show compliance. The probable range of variations, in service, of the damping action are an important part of the assessment. The test may be conducted in conjunction with the testing required by § 29.241. See paragraph AC 29.241.

(i) Analysis and tests may be used.

(ii) Reliable service history of identical or closely similar systems may be used. The materials and fluids used, clearance or fits, seals, and physical installation are important items to be evaluated and considered for “closely similar” systems.

(iii) Testing of the complete rotorcraft may be used to prove that malfunction of a single means of the damping system will not cause ground resonance. One method of demonstrating acceptable compliance is by removing all seals, if practicable, from one damper. Another method is to remove all or most of the fluid, in conjunction with considering the allowable ranges of damping of the other parts of the rotorcraft damping system and operating the rotorcraft throughout the rotor speed range from start to maximum rotor speed. Investigation of elastomeric dampers may require innovative test procedures and preliminary discussions of these prior to preparation of a test proposal. The rotorcraft cyclic control should be displaced as noted in paragraph AC 29.241 to assure that the possible rotorcraft resonance frequencies are excited. If vibrations are damped in all tests, the damping system is satisfactory. Each critical rotor damper and landing gear damper, which includes shock struts and tires, should simulate a malfunction to comply with the standard. The testing discussed, however, could become very extensive if one were to attempt to test all combinations of all maintenance adjustments of all components which contribute to the prevention of ground resonance, while at the same time rendering each of the pertinent components ineffective in turn and then repeating all of the maintenance tolerance testing each time. Fortunately, rational analytical methods are available which will permit the evaluation of such combinations so that only the combinations with the least amount of margin used are physically tested.

(2) The pylon damper variation can affect ground resonance. The variations in stiffness and/or damping of pylon mounts should be evaluated except the pylon mounts on contemporary conventional rotorcraft may have little influence on “classical” ground resonance stability. The dynamics of the rotorcraft on its landing gear is generally established by the airframe properties and the landing gear properties under the

influence of the rotor system, with the “pylon” having little effect. For air or flight resonance, the rotor generally couples with the rigid body modes of the fuselage. For a specific design, a relatively simple analysis may be used to show the effect of the pylon mount system stiffness on air and ground resonance stability, and if not important, variations in the system may be omitted from the test program.

(3) The probable ranges of damping shall be established and investigated as prescribed and noted in paragraph (b) of § 29.663. An approved test proposal and test results report should be used for complying with § 29.663(b). For example, if a conventional wheel landing gear is used on the rotorcraft, the probable ranges of tire pressure or the lowest probable tire pressure should be stated in the test proposal and effects of the tire pressure investigated during the test. In addition, the effects of strut pressures should be investigated also. See paragraph AC 29.241, § 29.241, concerning tests and instrumentation of the test associated with complying with § 29.241. The instrumentation noted in paragraph AC 29.241 also applies to § 29.663(b).

(4) If the wheel landing gear is equipped with wheel brakes, the evaluation should include brakes “on” and “off.” The nose or tail wheel should be locked and unlocked if it swivels to evaluate any possible adverse effects of this feature.

AC 29.663A. § 29.663 (Amendment 29-30) GROUND RESONANCE PREVENTION MEANS.

a. Explanation. Amendment 29-30 clarifies that analysis as well as tests may be used to show freedom from ground resonance after malfunction or failure of a single means of ground resonance prevention. This amendment primarily clarifies that the probable range of damping should be established as well as investigated.

b. Procedures. The procedures of paragraph AC 29.663 continue to apply with the addition of the need to document the establishment of probable range of damping of ground resonance prevention means. Acceptable tire and oleo minimum and maximum pressures as well as other identified factors should be documented in maintenance instructions if necessary to assure the desired characteristics.

SUBPART D - DESIGN AND CONSTRUCTION

CONTROL SYSTEMS

AC 29.671. § 29.671 (Amendment 29-24) CONTROL SYSTEMS - GENERAL.

a. Explanation.

(1) The rule requires that controls operate easily and smoothly and provide positive response of the rotorcraft to control input.

(2) In addition, the rule requires that incorrect assembly be prevented by special design features or special markings.

(3) After Amendment 29-24, November 6, 1984, the rule requires that the flight control system be designed such that the full range of flight control authority can be verified by the pilot before flight. This check would normally have to be completed prior to turning the rotor since control extremes typically cannot be reached with the rotor operating on the ground.

b. Procedures.

(1) Easy, smooth operations of controls are substantiated by the operations tests of § 29.683 and the FAA/AUTHORITY flight testing under TIA procedures. Positive response of the rotorcraft to control inputs is also evaluated during company flight testing and FAA/AUTHORITY TIA flight testing to the requirements of §§ 29.141 through 29.175.

(2) To meet the requirement that incorrect assembly be prevented, the preferred method is providing design features which make incorrect assembly impossible. Typical design features which can be used are different lug thicknesses, different member lengths, or significantly different configurations for each system component. In the event that incorrect assembly is physically possible (because of other considerations), the rule may be met by the use of permanent, obvious, and simple markings. Permanent (durable) decals or stencils may be used.

(3) Design features of the control systems are checked when reviewing the type design drawings. During the proof and operation tests of §§ 29.681 and 29.683, the controls should be thoroughly reviewed for possible incorrect assembly and for any required markings supplied for compliance with this standard.

AC 29.672. § 29.672 (Amendment 29-24) STABILITY AUGMENTATION, AUTOMATIC, AND POWER-OPERATED SYSTEMS.

a. Explanation.

(1) This rule requires that the pilot be made aware of stability augmentation, automatic, or power-operated system failures which could lead to an unsafe condition. Examples of clearly distinguishable warnings include, but are not limited to, an obvious aircraft attitude change following the failure or an audio warning tone. A visual indication itself may not be adequate since detection of a visual warning would normally require special pilot attention. The use of devices such as stick pushers or shakers is not acceptable as a warning means. However, this rule is not intended to eliminate the use of such devices for other purposes. Examples of automatic control systems other than a stability augmentation system would be a pitch axis actuator used for the purpose of demonstrating compliance with longitudinal static stability requirements or a fly-by-wire elevator. The design of such systems must not interfere with completion of the control checks described in § 29.671(c). Further, for control systems where a series actuator malfunction could degrade control authority, a means should be provided to the pilot to determine actuator alignment (see § 29.1329(b)).

(2) The corrective flight control input following a system failure should be in the logical direction. For example, a malfunction resulting in a nosedown pitch of the aircraft should require a corrective cyclic control input in the aft direction. The system deactivating means does not have to be located on the primary flight control grips; however, it should be easily accessible to the pilot. Malfunctions and subsequent recoveries must be shown throughout the operating envelope of the aircraft. In a case where control authority is decreased following a malfunction, a reasonable flight envelope must be defined wherein compliance with controllability and maneuverability requirements can be demonstrated. This reduced flight envelope must be presented in the flight manual. Compliance with trim and stability characteristics is not required following a malfunction; however, a pilot workload assessment should be made to show that a mission can be safely continued to completion following the worst case single failure.

b. Procedures. A discussion of malfunction test procedures is presented in paragraph AC 29 Appendix B b(6). Controllability and maneuverability test procedures are addressed in paragraph AC 29.143.

AC 29.673. § 29.673 (Amendment 29-24) PRIMARY FLIGHT CONTROLS.

a. Explanation. This section basically defines primary flight controls as “those used by the pilot for immediate control of pitch, roll, yaw, and vertical motion of the rotorcraft.” This section clarifies the application of § 29.1555 which requires markings for controls other than “primary flight controls or control(s) whose function is obvious.”

b. Procedures. The primary flight controls (e.g., cyclic stick, collective, and tail rotor pitch control pedals) are excluded from the marking requirements of § 29.1555.

AC 29.674. § 29.674 (Amendment 29-30) INTERCONNECTED CONTROLS.

a. Explanation. A new § 29.674 is added by Amendment 29-30 which requires that the rotorcraft be capable of safe flight and landing after a malfunction, failure, or jam of any auxiliary interconnected control.

b. Procedures.

(1) Section 29.674 requires that the rotorcraft be shown to be capable of safe flight and landing after a malfunction, failure, or jam of an auxiliary control interconnected with a primary control. The section does not apply to interconnected primary controls; e.g., cyclic and collective controls.

(2) Examples of auxiliary controls covered by this section may include certain autopilot or stability augmentation or trim system components. Section 29.1309 methods may be used in determining failure effects of autopilot and stability augmentation system components.

(3) If an engine control could jam and result in a collective control jam, these controls should be designed to relieve that connection.

AC 29.675. § 29.675 (Amendment 29-17) STOPS.

a. Explanation.

(1) Stops are required to prevent unrestrained movements of pilot/autopilot inputs from causing interferences or overloads.

(2) The rule requires that the stop must not appreciably affect the control system range of travel due to wear, slackness, or take-up adjustments.

(3) Each stop is required to withstand loads corresponding to design conditions.

(4) In addition, each main rotor blade, if appropriate for the design, must have stops to limit its travel about its hinge points. For rotors with hingeless design, stops may be provided as appropriate to limit blade travel. Loads which may result from the blade hitting the stops (during starting or stopping the rotor, or during any large but allowable pilot control inputs such as autorotation cyclic traverse or when subjected to ground gusts, etc.) shall not overload the stops nor any rotor component.

b. Procedures.

(1) Stops are generally provided in the cockpit area and near any controllable surface end of the control system (i.e., main rotor hub, tail rotor hub, and stabilizer activators). For systems with control coupling or series actuators, stops have been

located further away from the cockpit to permit increased control output during malfunction (hardover) or extreme control position cases.

(2) Location of stops in close proximity to each end of a control system will allow the stops to function most efficiently without undue deflections between the stops and the adjacent surface or the adjacent cockpit control lever or pedals. The location of stops close to the control lever or surface will help meet the requirement that the stop and its function not be appreciably affected by wear, slackness, or take-up adjustments. Consideration should be given to limiting the total amount of take-up adjustments of both the stop and the control systems to preclude a hazardous adjustment of the control surface range of travel.

(3) Each stop is to be substantiated for critical design conditions from either pilot effort, aerodynamic loads, hydraulic loads, or other critical loads, as applicable. The stops can be substantiated for limit loads by the tests of § 29.681. (Deliberate misrigging of the controls on the test aircraft may be necessary to assure that the maximum limit load which the stop will be subjected to in service is applied to the stop during these tests.)

(4) The stops to limit the main rotor blade about its hinge points should be positioned to prevent the blades from striking any part of the structure, particularly during startup and shutdown operations. These stops should also limit the flapping of the static main rotor blades of the rotorcraft when they are subjected to ground gusts or rotor wash from nearby taxiing rotorcraft. Provisions should be made to prevent overloading the stops or the blade under conditions of ground gusts, rotor wash effects, or during autorotation landing flares. The need for provisions to prevent possible overloads due to ground gusts and close taxiing by adjacent rotorcraft and by autorotation landings can be determined using the instrumented flight load survey aircraft by hover-taxiing another rotorcraft near the instrumented aircraft and by conducting autorotation landing flares with the instrumented aircraft. Substantiation for the final main rotor flapping stop design can be demonstrated by similar tests.

(5) If features of design are added to the main rotor stop assembly which activate certain portions of the stop assembly only on the ground to meet the requirement that the blade not hit the droop stop during any operation other than starting and stopping the rotor, such features of design must be substantiated to reliably operate by both ground tests and flight tests, as appropriate. Wear and rigging tolerances should be considered in these demonstration tests.

AC 29.679. § 29.679 CONTROL SYSTEM LOCKS.

a. Explanation.

(1) Whenever a control system lock or locks are used, the standard requires design features to prevent flight or limit operation before flight begins with the lock engaged. Locks are not required by the standard.

(2) After flight begins, design features shall be used when needed to prevent possible lock engagement while the rotorcraft is in flight or ground operation.

(3) The standard applies to external control locks as well as internal locks.

b. Procedures.

(1) Locks that release or disengage automatically, as stated, may be used. Attention should be directed to reviewing possible means of lock engagement while in flight. Fault analysis of the system should be used to ensure possible failures are determined. Design features may be used or needed to preclude this event.

(2) Manually applied and released locks may be used. Design features of the locks must prevent engagement in flight also.

(3) Any "unmistakable" warning to prevent takeoff with a lock engaged should be easily discernable during day and night operations. It should be possible to apply the lock only in such a manner that the required warning is provided. Color, location, shape (identification), and accessibility of the device or its control and legibility of any device placards or markings are important considerations in the evaluation.

(4) During a "compliance inspection," and during TIA evaluations, the locks shall be evaluated to the standards. When a lock is not automatically disengaged, the operation of the rotorcraft should be limited. Unmistakable warning may be achieved as follows.

(i) Prevent sufficient power for takeoff.

(ii) The pilot shall be unable to move the collective control from the lowest pitch limit.

(iii) One or more aural devices that cannot be disengaged (turned off) until all locks are removed.

AC 29.681. § 29.681 LIMIT LOAD STATIC TESTS.

a. Explanation.

(1) The rule requires static tests of the control system in showing compliance with limit load requirements.

(2) The tests are specified to include each fitting, pulley, and bracket of the control system being tested and to include the "most severe loading."

(3) Also, the rule requires that compliance with bearing factors (reference § 29.623) be shown by individual tests or by analyses for control system joints subject to motion.

b. Procedures.

(1) Compliance with the requirements of this rule is obtained by static tests conducted on either a static test airframe or on a prototype flying ship. In either case, conformity of the control system and related airframe is necessary to validate the tests.

(2) The rotor blades or aerodynamic surfaces may be used to react pilot effort loads through the control system or they may be replaced with fixtures. If fixtures are used, they should be evaluated for geometric and stiffness effects to assure test validity.

(3) The loads to be applied during the limit load static tests are specified in §§ 29.395, 29.397, and 29.399. The loads are applicable to collective, cyclic, yaw, and rotor blade control systems as well as any other flight control systems provided by the design.

(4) Section 29.585(e) specifies bearing factors for control system joints subject to angular motion. These factors are 3.33 for push-pull systems and 2.0 for cable systems for joints with plain bearings. For joints with ball or roller bearings, use the manufacturer's ratings.

AC 29.683. § 29.683 OPERATION TESTS.

a. Explanation. The rule requires that the control system be free from jamming, excessive friction, and excessive deflection. An operational test is required in which specified loads are applied at the pilot controls and carried through an operating control system.

b. Procedures.

(1) Compliance with the requirements of this rule is obtained by use of a test setup similar to that used for the limit load tests of § 29.681, except the load reactions at the blades (or surfaces) must allow for movement of the blades (or surfaces) as the system is operated through its operating range.

(2) Fixtures are normally affixed to the surfaces (or replace the surfaces) to allow pulley arrangements which provide for movement under load. These fixtures should be evaluated to assure that system loads up to limit will be applied during the full range of operations of each system.

(3) Each flight control system should be operated through its entire range under a light load and under limit load. As the controls are being operated, the system

should be checked for jamming, excessive friction, and excessive deflection. Excessive deflection includes deflection sufficient to contact other systems or structure. Also (in agreement with CAM 04.331/04.43.11), FAA/AUTHORITY policy has been to consider as excessive the deflection of a control system under limit load which exceeds approximately one-half of the system travel from neutral to an extreme stop. Floor panels, wall panels, and other access panels may have to be removed to permit visual checks of the entire control system. However, care should be taken when removing panels so that airframe structure is not weakened enough to deflect from its normal position when test loads are applied to the control system.

AC 29.685. § 29.685 (Amendment 29-12) CONTROL SYSTEM DETAILS.

a. Explanation. The rule requires that the control system be designed to prevent chafing, jamming, and interference from cargo, passengers, loose objects, or the freezing of moisture. Specifically, means are required in the cockpit to prevent the entry of foreign objects into places where they would jam the system, and means are required to prevent the slapping of cables or tubes against other parts. Specific design considerations to prevent binding and overloads within the control system are required such as--

(1) Assure pulley-cable combinations as specified in MIL-HDBK-5 are used unless inapplicable.

(2) Assure close fitting pulley guards are provided.

(3) Assure pulley-cable alignment sufficient to prevent excessive pulley flange loads is provided.

(4) Assure fairlead-cable alignment is within 3°.

(5) Assure no clevis pins are retained only by cotter pins.

(6) Assure turnbuckles do not bind other structures throughout the range of travel.

(7) Assure means for inspection of control system components are provided.

(8) Assure control system joints subject to angular motion incorporate special bearing factors, 3.33 for push-pull systems and 2.0 for cable systems.

(9) Assure that manufacturer’s ratings for ball or roller bearing ratings are not exceeded.

b. Procedures.

(1) The geometry of the control system components and installations is the primary control to prevent chafing, jamming, and interference. The control system from cockpit to surface should be checked for clearances both unloaded and loaded. The control system should be checked under load during both the limit load static tests (reference § 29.681) and the operational tests of § 29.683. Location of guides or fairleads and pulleys may be used in cable systems to prevent chafing and interference with other structure. Generally, tubes should clear adjacent structure by location and design geometrical considerations. If supplemental means are provided to assure the tubes do not chafe or interfere, the means should be evaluated for possible jamming.

(2) Rubber (or other elastomeric) boots connected to both the cockpit control arm or shaft and to the floor are acceptable means to prevent the entry of foreign objects into underfloor areas where they may cause jamming of controls. Control systems should, in general, be routed around cargo compartments. If routing of the control system components is in or near cargo areas, the control system components should be protected by bulkheads, panels, or other enclosures which have sufficient strength and stiffness to prevent possible interference with the control system components when subjected to cargo loading and handling deflections.

(3) Control system details should be reviewed for possible moisture collection. Areas should drain free. Exposed or open control areas should drain free, and areas of possible freezing moisture collection should not accumulate ice that would cause a jam of the controls. Simulated or actual ice collection on the controls may be used to prove questionable features. The areas to be considered for moisture collection include both external and internal areas where moisture may accumulate by direct impingement of water, entrapment of water particles, or condensation of moisture.

(4) The latest revisions of MIL-HDBK-5 do not explicitly give approved pulley-cable combinations, but appropriate MIL specifications are given in Chapter 8.3 for use in determining pulley-cable combinations and ratings.

(5) Provide ratings, factors, and alignment as specified.

(6) Provide inspection means as specified.

(7) Provide close fitting pulley guards as specified.

AC 29.687. § 29.687 SPRING DEVICES.

a. Explanation.

(1) This standard for control systems assures that springs and spring devices used to prevent flutter, control oscillations, or vibrations are either --

(i) Reliable; or

(ii) The failure is not critical to the rotorcraft.

(2) Tests simulating service conditions are required in either instance.

b. Procedures.

(1) Springs and spring devices used in the control system, including balance springs, should be identified early in the certification program.

(2) If a spring cannot be shown by observation or analysis to be noncritical, then ground or flight tests may be required.

(3) Springs that are critical to safe operation may be subject to fatigue substantiation to prove they are reliable for the operating conditions imposed in service.

(4) Springs used in conjunction with hydraulic actuator spool valves may be subject to the standards of § 29.695.

AC 29.691. § 29.691 AUTOROTATION CONTROL MECHANISM.

a. Explanation.

(1) Rotorcraft designs generally have a main rotor blade collective pitch control system that does not have detents or other devices to limit pitch control in the control mid-range. Autogyro and other rotorcraft designs may include detents or other finite position control for collective pitch control. This rule requires that the control design allow rapid entry into autorotation after a power failure.

(2) Section 29.33 contains standards concerning establishment and control of the main rotor speed limits. The standard requires flight tests and demonstrations. The standard also concerns rotorcraft design features that are related to control of the main rotor speed limits. Paragraph AC 29.33, § 29.33, pertains to this standard.

(3) Other design requirements for control systems are contained in § 29.685.

b. Procedures.

(1) If high and low main rotor pitch stops are employed in the collective control and if the control may be rapidly moved from one limit to the other, compliance is shown.

(2) If detents or intermediate stops are employed, the pilot must be able to easily and readily override, disconnect, remove, or bypass the device to allow rapid autorotation entry prior to exceeding transient low speed rotor limits. An early assessment for design deficiencies may be accomplished by the flight test personnel with the evaluation completed in the Type Inspection Authorization (TIA) test program.

(3) It is acknowledged that modern rotorcraft designs may have an autorotation V_{NE} that is lower than power-on V_{NE} or normal cruise speed. For rotorcraft designs with this characteristic, the speed must be reduced after entry into autorotation. The rule also applies to rotorcraft designs with this characteristic and no relief from the rule is required since many phases of operation occur at speeds less than power-on V_{NE}. For example, a critical phase of flight occurs during takeoff. Rapid entry into autorotation is essential during this phase also.

(4) The features of the autorotation control mechanism and ability to control the rotor speed within the design limits for any rotorcraft will be evaluated as an integral part of the TIA test program.

AC 29.695. § 29.695 POWER BOOST AND POWER-OPERATED CONTROL SYSTEM.

a. Reference Regulations. The following sections of Part 29 are either incorporated in the provisions of § 29.695 or are otherwise applicable to power boost and power-operated control systems:

(1) Section 29.307 Proof of structure.

(2) Section 29.571 Fatigue evaluation of fight structure.

(3) Section 29.681 Limit load static tests.

(4) Section 29.685 Control system details.

(5) Section 29.861 Fire protection of structure, controls, and other parts.

(6) Section 29.863 Flammable fluid fire protection.

(7) Section 29.1301 Function and installation.

(8) Section 29.1309 Equipment, systems, and installations.

b. Explanation.

(1) The rule requires an alternate system if a power boost or power-operated control system is used.

(2) The alternate system must, in the event of any single failure in the power portion of the system, or in the event of failure of all engines:

(i) Be immediately available.

(ii) Allow continued safe flight and landing.

(3) The alternate system may be:

(i) A duplicate power portion of the system; or

(ii) A manually operated mechanical system.

(4) The power portion of the system includes:

(i) The power source (such as hydraulic pumps); and

(ii) Items such as valves, lines, and actuator.

(5) The failure of mechanical parts (such as piston rods and links) must be considered unless their failure is extremely improbable.

(6) The jamming of power cylinders must be considered unless their jamming is considered extremely improbable.

c. Procedures. It is assumed in the following discussion that the power boost or power-operated control system being utilized is a typical aircraft hydraulic system.

(1) The rule requires, without regard to the probability of failure, an alternate system for the power portion of the system. The power portion of the system, by example in the rule, includes hydraulic pumps, valves, lines, and actuators. It has also been interpreted to include seals, servo valves, and fittings.

(2) If a duplicate power portion of the system is used to meet the requirements of the rule, the requirements may be met by providing a dual independent hydraulic system, including the reservoirs, hydraulic pumps, regulators, connecting tubing, hoses, servo valves, servo-valve cylinder, and power actuator housings. There must be no commonality in fluid-carrying components. A break in one system should not result in fluid loss in the remaining system.

(3) Dual actuators should be designed to assure that any single failure in the duplicated portion of the system, such as a cracked housing, broken interconnecting input, or broken interconnecting output link, does not result in loss of total hydraulic system function.

(4) A manually operated mechanical system may be used as the alternate system to a single hydraulic system if, after the loss of the single hydraulic system, the pilot can control the rotorcraft without undue mental or physical fatigue in any normal maneuver for a period of time as long as that required to effect a safe landing.

(5) The substantiation of the various system components should include consideration for operation in the normal and alternate system modes.

(6) The "extremely improbable" criteria noted in § 29.695(c) for failure of mechanical parts may be satisfied by performing component fatigue testing and establishing a service life through this technique.

(7) Fatigue substantiation of the control actuator is required under § 29.571 and should consider both the stresses imposed by flight loads and the stresses imposed by hydraulic pump pressure pulses. Flight loads factored in a suitably conservative manner may be an acceptable means to take into account both effects.

(8) The possibility of jamming of the power cylinder may be shown as "extremely remote" through a failure analysis that considers every possible system component failure such as, but not limited to, ruptured lines, pump failure, regulator failure, ruptured seals, clogged filters, jammed servo valves, broken interconnecting servo valve inputs, broken interconnecting output links, etc.

(9) Three acceptable means to meet the requirements of § 29.695(a)(2) could be as follows:

(i) Provide two transmission-driven hydraulic pumps, provided the pumps are driven by the transmission during all flight conditions including autorotation.

(ii) Use two electrically driven hydraulic pumps if electrical power is available to drive the pumps with all engines failed. If this approach is used, the battery must be capable of running both pumps plus all other required equipment necessary for continued safe flight.

(iii) Use a single transmission driven pump and an electrically driven pump.

SUBPART D - DESIGN AND CONSTRUCTION

LANDING GEAR

AC 29.723. § 29.723 SHOCK ABSORPTION TESTS.

a. Explanation.

(1) Limit and "reserve energy" drop tests are required as prescribed in §§ 29.725 and 29.727, respectively. These tests must be conducted on the complete rotorcraft or on units consisting of wheel, tire, and shock absorber in their proper relation. For rotorcraft with skid landing gear, the tests may be conducted on the complete rotorcraft or on a simulated fuselage with the complete skid landing gear system.

(2) The rotorcraft must be designed to limit load factors that equal or exceed the limit load factor substantiated by these drop tests. In practical application, the rotorcraft may be designed to a limit load factor, such as 2.8 g. Thus, it is necessary that the limit landing load factor derived from the landing gear drop tests be equal to or less than 2.8 g. If not, the rotorcraft must be redesigned for the higher load factor derived from the drop tests. It must be shown in accordance with § 29.723 that the limit load factors selected for design under § 29.473 will not be exceeded in landings with the limit descent velocity corresponding to the drop height specified in that section. In addition, reserve energy absorption capacity of the landing gear must be shown for a descent velocity of 1.22 times the limit descent velocity selected under § 29.473 by increasing the drop height to 1.5 times the "limit" drop height. The test requirements or procedures outlined in FAR 29 for obtaining the landing load factors are empirical; however, these procedures are based on and supported by satisfactory experience.

(3) As stated in § 29.725(c), each landing gear unit should be tested in the attitude simulating the landing condition that is most critical from the standpoint of the energy to be absorbed by it.

(i) For wheel landing gear designs, the level landing or tail down landing and level landing with drag are generally the most critical attitude. A test of more than one attitude is generally required to comply with the standard. The landing attitudes or conditions prescribed are level (vertical loads), inclined (loads at 14.5° aft from the vertical axis), level with wheel spin-up and tail down. These attitudes are specified in §§ 29.479(b)(1), (2), and (3) and 29.481.

(ii) For skid landing gear designs, the level landing and level landing with drag are generally the most critical attitudes. These attitudes are specified in § 29.501(b) and (c).

(4) Drop tests are required. If analytical methods and/or means are proposed by the applicant, the data presented for approval must be equal to or conservative with

respect to that data obtained from physical drop tests. Section 21.21(b)(1) of FAR 21 concerns “equivalency” determinations. Presenting an acceptable means of “equivalency” here would circumvent the necessary scrutiny of an analytical method or means and is also beyond the scope of this document.

b. Procedures. The test plan or proposal must be approved prior to official FAA/AUTHORITY tests unless satisfactory resolution of outstanding proposal or conformity inspection items can be accomplished after the test.

(1) The following headings would be a typical table of contents for the test proposal, and a generalized explanation of the contents that may be included under each of these headings for a wheel landing gear follows.

(i) Purpose. The regulations to which compliance is being shown by the drop tests should be identified (usually §§ 29.723, 29.725, and 29.727). Also, the rotorcraft landing gear including the wheels and tires to be dropped, should be positively identified in the report by the manufacturer’s or applicant’s previously FAA/AUTHORITY approved drawing, technical standard orders (TSO’s), or other identifying FAA/AUTHORITY approved data as applicable.

(ii) Description of test setup. This section should present a description of the test fuselage or jig, method of attaching landing gear to jig, and type of accelerometer to be used to measure load factors. Proof of calibration of accelerometer should be available. The accelerometer should be mounted at the aircraft CG if a free drop of the aircraft is used, or as close as practical to the centerline of the main shock absorbing component of each landing gear (oleo strut, etc.) if each gear is tested separately. The description of the test jig, including platforms on which the gears are to be dropped, should be defined by sketches in addition to the required mathematical calculations. This data should show that the landing gear will be at the proper attitude, relative to the platform, on impact for the particular landing condition. Drawings or other approved data from which the geometry is taken should be referenced in the proposal. The tire and oleo pressures at the time of the test should be specified. The method of measuring the deflection of the tire plus the vertical travel of the axle under impact should be described. This measurement may be accomplished by telescoping tubes attached to the point on the jig that would measure the total (tire and oleo) vertical deflection of the landing gear. Other vertical and horizontal deflections should be measured as required to determine if the landing gear has experienced permanent deformation after each drop test. The effect of surface roughness should be considered. Smooth surfaces tend to give maximum deflections where rough surfaces tend to restrict deflection and to result in maximum values of N_Z. Preliminary company drop tests (at less than limit drop height) may be used to determine the critical surface roughness, or engineering evaluations may be used (without tests) when the gear configurations are such that the critical surface condition can be analytically determined (or when the load factor is shown to be negligibly affected by surface roughness). NACA Report 1154, dated 1953, contains information that surface coefficients of friction may vary from 0.4 to 0.7. Skid landing gear standards, § 29.501(c), indicate an acceptable coefficient of friction is 0.5. A wheel landing gear design standard, § 29.479(b), indicates an acceptable coefficient of friction is 0.25. In the case of a small rotorcraft, the entire aircraft may be dropped. This may be accomplished by establishing pivot points at the main gear axles for the tail (or a point forward of the nose gear) drops, and a pivot point at the tail (or nose gear) axle for the main gear drops. It is the responsibility of the applicant to distribute the aircraft inertia items, including added weight to get the proper effective drop weight (W_e) at the landing gear, so that no local failures of the aircraft occur as a result of the limit or reserve energy drop tests.

(iii) Test data. Computations for the required drop height (h) and the effective drop weight (W_e) should be shown for each design level landing and tail down landing condition in compliance with §§ 29.479 and 29.481. The computations should be in accordance with § 29.725(a) for h and § 29.725(b) for W_e for the limit drop tests. W_e and h are computed in accordance with § 29.725 for the limit drop test and with § 29.727 for reserve energy drop test. The computation of the static weight on the gear being dropped (W_M, W_N, or W_T) and used in the computation of W_e should be shown. This static weight is defined as W_M, W_T, or W_N for the main gears, tail gear, or nose gear, respectively, in § 29.725(d). It should be shown that the critical CG and proposed certificated maximum landing weight have been used in the computation of W_M, W_T, or W_N. The computation of the slope of the platforms required for the inclined reaction conditions should be presented also.

NOTE: Effective drop weight (W_E) is used only for free drops. It provides a technique for accounting for rotor lift without applying lift during the test. If rotor lift is applied during the drop tests, actual weights (W_M, W_T, or W_N) will be used, not effective weights, W_E.

(iv) Test results. The results of the test are based on the values of W_E, h, d, W, and L used and obtained for each drop test and the value of Nj obtained from the accelerometer. These results should be summarized, and the method of computing the aircraft limit inertia load factor should be shown for each drop in accordance with § 29.725(d). A print or copy of the film or other recording trace from the accelerometer, if not a direct readout type of accelerometer, should be included in the test results. Each critical condition should have several preliminary drops as many times as required to obtain reasonable correlation.

(2) Skid landing gear may be tested using similar procedures except a level landing attitude drop test is all that is required by § 29.501. The design load conditions specified in § 29.501(c) through 29.501(f) are derived from this level drop test condition.

(i) Section 29.501, paragraphs (a)(2) and (3), contain special considerations for skid landing gear.

(ii) Section 29.501(a)(2) specifies that structural yielding of elastic spring members under limit load is acceptable. This yielding or deformation is a means of absorbing the landing impact. For skid landing gear that use oleo or other types of shock absorbers, the standard does not allow structural yielding under limit load. During the limit load and reserve energy (ultimate for skid landing gear with elastic spring numbers) drops, the yielding energy absorbing members will probably deform or yield. After a limit drop test, the gear may be used for a reserve energy drop at the discretion of the applicant but a gear that has been subjected to a reserve energy drop should not be used unless it can be shown that no yielding has occurred in that gear.

(3) Wheel landing gear is tested in attitudes prescribed in paragraph a(3)(i) above. Each unit, nose or main gear, is generally tested separately.

(4) Skid landing gear is tested in attitudes prescribed in subparagraph a(3)(ii) above. Due to the construction of skid landing gear, the complete skid landing gear is tested as a unit. Thus, the level landing with drag condition is probably the critical attitude for the forward cross-tube and its attachments. The level landing condition is probably the critical attitude for the aft cross-tube and its attachments.

(5) An FAA/AUTHORITY or FAA/AUTHORITY designated or delegated person need only witness the drop tests for “record” or “compliance.” Preliminary or developmental drops do not require an FAA/AUTHORITY witness.

AC 29.725. <u>§ 29.725 (Amendment 29-3) LIMIT DROP TEST</u>.

a. <u>Explanation</u>. Limit drop tests, in the critical aircraft attitude or critical attitude of each gear, are required for the landing gear. The drop height must be at least 8 inches, which equates to 393 feet per minute (free fall) vertical descent speed. Rotor lift may be simulated and an effective mass may be used in the drop test as prescribed.

b. <u>Procedures</u>. See paragraph AC 29.723, § 29.723.

AC 29.727. <u>§ 29.727 RESERVE ENERGY ABSORPTION DROP TEST</u>.

a. <u>Explanation</u>.

(1) In addition to the limit drop tests, a reserve energy drop test is required. The landing gear must not collapse in this test to the extent that the fuselage impacts the ground. Fracture (to separation) of landing gear parts is considered collapse of the landing gear. This test is not an ultimate load drop test for the landing gear, except as specified in § 29.501(a)(3) for certain skid landing gear designs using elastic spring members.

(2) All other types of landing gear must be substantiated for design ultimate loads in addition to this reserve energy drop test.

(3) Shock absorbing devices, such as oleos, must not “bottom” during the reserve energy drop test. “Bottoming” occurs when displacement of the device no longer occurs with increasing load.

(4) Requirements for proof of the landing gear and airframe structure are found in §§ 29.305, 29.307, and 29.473.

b. Procedures. See paragraph AC 29.723, § 29.723.

AC 29.727A. § 29.727 (Amendment 29-30) RESERVE ENERGY ABSORPTION DROP TEST.

a. Explanation. Amendment 29-30 defines the word “collapse” as used in § 29.727(c). Collapse of the landing gear during reserve energy absorption drop tests occurs when:

(1) A member of the landing gear will not support the rotorcraft in the proper attitude; or,

(2) A member deforms sufficiently to allow the rotorcraft structure other than the landing gear and external accessories to impact the landing surface.

b. Procedures. The procedures of paragraph AC 29.727 continue to apply with the following supplemental guidance.

(1) The proper attitude for the rotorcraft after the reserve energy absorption drop test is an attitude which allows for permanent deformation of landing gear elements but provides for adequate egress from the rotorcraft.

(2) External accessories that may not impact the landing surface during drop testing include devices such as externally mounted fuel tanks or accessories likely to cause post-landing fires. Cameras, loudspeakers, and search lights may be damaged during deformations resulting from reserve energy drop tests if electrical connections are sufficiently protected to preclude electrical fires and the devices are not likely to penetrate fuel tanks. The expendable accessories, if installed, should also be designed to not have “hard points” that would unacceptably damage the rotorcraft structure under landing impacts by penetration into the occupied areas or fuel tanks. These expendable accessories should be designed with frangible fittings, frangible devices, or comparable design features. Also, these devices should be designed to not significantly alter the energy absorbing ability or design features of the landing gear.

AC 29.729. § 29.729 (Amendment 29-24) RETRACTING MECHANISM, LANDING GEAR.

a. Explanation.

(1) Structural substantiation is required for the gear, retracting mechanism, doors, gear supporting structure for landing loads, maneuvering, gusts, and yawing flight condition loads.

(2) An emergency means to extend the gear after failure of the retraction/extension system is required for all except solely manual mechanical systems.

(3) This regulation requires an indication to the pilot when the gear is secured in the extreme positions. This rule does not apply to rotorcraft with fixed gear. The rule also applies to amphibious rotorcraft with retractable gear.

(4) A landing gear down-lock is required. An optional up-lock may be used if it meets reliability requirements.

(5) A (ground) operation test must be conducted to ensure proper functioning of the system.

(6) Location and operation of the control lever or device must comply with § 29.777. This section includes identification of controls to prevent confusion and inadvertent operation. Sections 25.779 and 25.781 of FAR Part 25 contain large airplane design requirements for motion, effect, and shape of cockpit controls and their knobs and should be consulted for further guidance.

b. Procedures.

(1) The design load factors and resulting loads should be derived from the design data. The landing gear, while retracted, operating, and extended, and its supporting structure should be substantiated for the critical aerodynamic and inertia loads. Yawed conditions should be considered. The specific conditions are noted in paragraphs (a)(1), (2), and (3) of § 29.729.

(2) Wheel well doors, if installed, should be designed for the aerodynamic loads, including loads from yawing conditions (angles proven under § 29.351) for airspeeds up to the design maximum landing gear extended speed. Aerodynamic effects on both open and closed doors must be considered in the door and door support substantiations. The applicant may choose to substantiate the rotorcraft for a “landing gear operating” and “extended” speed V_{LO} and V_{LE}, respectively, that is equal to the rotorcraft V_{NE}. This option will alleviate an airspeed “structural limitation” because of the landing gear design substantiation. Any airspeed “structural limitation” should be listed in the structural limitations part of the TIA.

(3) The required “down-lock” should be checked during the operation test. The design drawing should be reviewed for compliance prior to conducting an operation test. The “down-lock” system should be evaluated for § 29.1309 function and reliability requirements.

(4) If an optional “up-lock” is installed (including hydraulic locking), the landing gear should be extended during the operation test after simulation of critical failure mode of the retraction system (reference § 29.1309).

(5) An “operation” test plan or proposal submitted for compliance with § 29.729(d) should include the items noted in the two previous subparagraphs and should include a functional check of the position indicator system. Those tests must be satisfactorily completed before issuing the TIA.

(6) During the official FAA/AUTHORITY flight tests, compliance with the emergency operation, position indicator, and control aspect of § 29.729(c), (e), and (f), respectively, will be verified or accomplished. In addition, the F and R test program plan (§ 21.35) will specify certain tests or evaluations for the retraction system.

(7) Position Indicator Evaluation.

(i) When evaluating the position indicator system, emphasis should be placed on the switches and their installations, and on the cockpit presentation. Each gear must have its own set of switches to indicate when it is secured in its extreme “up” position and its extreme “down” position. The switches must be located to give a valid indication of the arrival of the gear at its extreme position.

(ii) The reliability and environmental qualifications of the switches to be used should be carefully considered. An example of a condition that has potential for trouble is operation on wet areas. Trouble starts when water is picked up by the tires and deposited on the switches. During winter months the water can freeze, and the resulting ice may prevent the switch from functioning properly.

(iii) An acceptable cockpit presentation consists of two lights for each gear. One light is colored “green” and indicates when its gear is secured in the extreme “down” position. The other light is colored “amber” or “red” and indicates when its gear is in transit. When the gear is in either extreme position, the in transit light is “out.” For this presentation, the indication to the pilot that the gear is in the extreme “up” position is an all-gear, lights-out condition.

(iv) Some manufacturers have also included a warning system to alert the crew if the landing gear has not been extended prior to landing. If a warning system is presented, §§ 29.1301 and 29.1309 should be used to evaluate its functional characteristics and the impact of its failure modes.

AC 29.731. § 29.731 WHEELS.

a. Explanation. This standard requires use of approved wheels, either approved under TSO-C26 or a later revision or approved under the type certificate for the aircraft. Wheels must satisfy both a design static (1g) load and design limit landing or taxiing load determined under the applicable ground load requirements. Standards for a tire installed on a wheel are contained in § 29.733.

b. Procedures.

(1) The structural design loads data shall contain both a static load and a landing and taxiing load for each wheel. These loads are determined by virtue of compliance with the standards of § 29.731(b) and (c). The ratings of the wheel shall not be exceeded. TSO-C26c contains minimum performance standards for TSO approval of aircraft wheels and wheel-brake assemblies. Ratings are assigned in accordance with this performance standard.

(2) If a wheel selected for an aircraft design has TSO approval, the wheel manufacturer will supply the rating to the aircraft manufacturer. Each wheel shall be marked as prescribed which includes a listing of the TSO number. Even though a wheel is TSO approved, the application on the aircraft (loads imposed on the wheel) requires proof that the rating is not exceeded.

(3) If a wheel selected for an aircraft design is not approved under a TSO, the necessary data, both detail design and assembly drawings and qualification tests and test report data, will be required to comply with the standards contained in Part 29. Design control and inspections will be accomplished as a part of the aircraft type design. Structural substantiation and any appropriate qualification tests shall be accomplished. See §§ 29.471 through 29.497 and § 29.511 for the ground load conditions.

(4) The Tire and Rim Association, Inc., generally issues a yearbook listing tire and rim sizes and ratings. The dimensions and contours for aircraft wheel rims are contained in Section 9 of this yearbook.

AC 29.733. § 29.733 (Amendment 29-12) TIRES.

a. Explanation.

(1) This standard specifies both design and performance criteria for tires. The tire must fit the wheel rim. The maximum static ground reaction for the condition specified must not exceed the maximum static load rating of each tire. In addition, any tire of retractable gear systems must have adequate clearance from surrounding structure and systems as specified.

(2) Main, nose, and tail wheel tires must comply.

(3) Rotorcraft design maximum weight shall be used. Static and “dynamic” conditions are specified for rotorcraft tires.

(4) Tire performance standards are contained in TSO-C62c.

b. Procedures.

(1) The aircraft structural design loads should contain a maximum static load imposed on the tires. The load is derived for a static ground reaction assuming the design (maximum) weight and the critical center of gravity for each tire of the landing gear. The wheel loads are determined under § 29.731(b). Reduced weight but forward CG conditions may result in the highest static load on a nose wheel tire. Thus, combinations of weight and CG locations require investigation for the maximum tire load of each main, nose, and tail wheel tire. Nose wheel tires are subject to a specific dynamic condition.

(2) The maximum possible size of the tires considering appropriate temperatures, aging, and pressure should be obtained to check wheel well and cover clearances. Tire dimensions (for clearances) may be found in the yearbook noted in paragraph AC 29.733b(4). If the tire clearance is questionable, objects may be taped to the tire to simulate tire growth or oversize dimensions expected and the wheel retracted and rotated by hand to check for possible interferences. Minimum clearance, such as one-half inch, may be adequate as a design objective. The design drawings should be reviewed for information of correct systems installations and landing gear rigging within the wheel wells and wheel covers, if installed. If necessary to control tire sizes, specific manufacturer's tires should be used as "required equipment" and the tire manufacturer and the part number should be specified in the design data and on the type certificate data sheet as "required equipment."

(3) As specified in § 29.729(d), an operation test of any retractable landing gear should be performed. During this operation test, the tire clearances should be determined and recorded for the maximum tire size expected in service. Only the least or minimal clearance found, if adequate, should be recorded.

(4) The Tire and Rim Association, Inc., generally issues a yearbook listing tire and wheel rim sizes and ratings. This information is advisory as stated in the yearbook. Section 9 concerns aircraft tires and rims. Table AP-5 in Section 9 of the yearbook concerns tires used on rotorcraft. The tire may be selected initially from the yearbook, but qualification data for the specific tires used shall be furnished with the type design data in compliance with the standards. Section 9 also contains tire size and tire growth dimensions.

(5) Minimum performance standards for aircraft tires, excluding tail wheel tires are found in TSO-C62c, Aircraft Tires. Tires meeting the TSO are marked as prescribed in the standards. The load rating (reference § 29.733) is marked on the tire. TSO tires are not required but should be used whenever possible. The manufacturer's information, such as load rating, should be included in the aircraft type design structural substantiation data.

AC 29.735. § 29.735 (Amendment 29-24) BRAKES.

a. Explanation.

(1) Brakes are required for wheel landing gear aircraft. Minimum performance standards are contained in this section. During the course of the FAA/AUTHORITY flight test program and of any F&R program conducted under § 21.35, the brakes shall be used and evaluated.

(2) Design criteria are contained in this standard.

(i) The braking device must be controllable by the pilot. It is optional for the second pilot station except as may be specified under the provisions of § 29.771.

(ii) The braking device must be usable during power-off landings.

(3) Performance criteria are also contained in this standard.

(i) The brakes must be adequate to counteract any normal unbalanced torque when starting or stopping the rotor or rotors.

(ii) The brakes must be adequate to hold the rotorcraft parked on a 10° slope on dry, smooth pavement.

(4) In §§ 29.493(b)(2) and 29.497(g)(2)(ii), limiting brake torque is one ground load standard for design of the landing gear.

(5) Although not specifically noted in a standard, the position of the brake on the wheel is important. The brake should be positioned to avoid ground contact whenever the tire is deflated.

(6) TSO-C26c contains minimum performance standards for aircraft landing wheels and wheel-brake assemblies. For rotorcraft, a wheel-brake assembly design rating is established by the manufacturer. The TSO standard for rotorcraft brakes specifies a 20° slope standard (rather than a 10° slope) for an over-pressure hydraulic brake test.

(7) The brake application device at the pilot station is subject to other structure strength standards in this Part, such as the limit pilot forces or torque specified in § 29.397.

b. Procedures.

(1) Wheel-brake assemblies approved under TSO-C26 or a later revision will have various (rotorcraft) ratings as specified in the standard. One rating of TSO standard for a rotorcraft wheel-brake assembly is the kinetic energy capacity in

foot-pounds at the design landing rate of absorption. The design takeoff and landing weight and rotorcraft speed in knots for brake application are a part of the equation. The brake manufacturer should furnish this rating and the two noted parameters for the selected design or designs. The ratings of selected brakes should be included in a structural design data report such as a design criteria report. The use or application of each brake design on the particular rotorcraft design should not exceed capacity of the brake or the ratings established under the TSO. If appropriate, the part number and manufacturer of each brake may be listed in the structural data reports as well as listed in the type design drawings.

(2) The limiting brake torque obtained from the brake manufacturer should be used in complying with §§ 29.493(b)(2) and 29.497(g)(2)(ii).

(3) Compliance with the brake standards should be confirmed, demonstrated, and recorded as a part of the flight test type inspection report. This applies to TSO brakes and to brakes approved as a part of the aircraft type design.

(4) If found necessary under the provisions of § 29.771, the second pilot station should have brake control devices. The brake control devices should be listed with the other required equipment that defines the equipment necessary for a second pilot station.

(5) A brake assembly may be evaluated and approved under Part 29 as a part of the aircraft type design. TSO-approved brakes are not specifically required but are recommended. For non-TSO-approved brakes, all detail and assembly drawings, required test proposals, and test results reports may be submitted and processed as a unique part of the particular aircraft type design.

(6) During an inspection of the landing gear, such as an engineering compliance inspection, the brake location should be checked to ensure the brake does not contact the ground when the tire is deflated. Type design drawings should control the proper location of the brake on the landing gear.

AC 29.737. <u>§ 29.737 SKIS</u>.

a. <u>Explanation</u>. This standard is, in part, derived from small airplane standards. Aircraft skis approved under TSO-C28 may be used on rotorcraft. TSO-C28 for aircraft skis refers to Sections 4 and 5 of National Aircraft Standards Specification 808, dated December 15, 1951, for strength and performance standards. The standard also addresses flight/aerodynamic loads.

(1) A maximum limit load rating is assigned to each ski approved under TSO-C28.

(2) This limit load rating must not be exceeded by the maximum limit ground load determined under the standards of § 29.505, Ski landing conditions.

(3) The ski installation is also subject to the maximum aerodynamic and inertia loads and to the ground rotation or torque load per § 29.505(c).

(4) Ski mounting or installation parts used in the particular application are subject to substantiation as any landing gear member is subject to substantiation.

(5) Ski installations are also subject to flight and ground operation evaluations.

(6) Pads or "bear paws" on skid or wheel landing gears for use in snow or soft soils are unique to rotorcraft. These shall be approved also. For new type certificate applications after November 27, 1989, § 29.571, Amendment 29-28 requires fatigue substantiation of the landing gear. The effect of pads, etc., shall be evaluated in compliance with the standard.

b. Procedures.

(1) The limit load rating for the ski selected shall be obtained from the ski manufacturer. This information shall be included in the design criteria and/or structural substantiation reports. The type design drawings will include the appropriate part number for the TSO-approved product and the necessary installation information.

(2) The design limit loads derived in compliance with § 29.505 shall not exceed the ski limit load rating. The skis shall be substantiated for the torque load in § 29.505(c) since the TSO standard does not contain a similar requirement.

(3) Skis that are not TSO approved may be approved as a part of the aircraft type design by complying with the strength and performance standards contained in TSO-C28 (NAS 808).

(4) The aerodynamic loads shall be based on a limit load design speed of 1.11 V_{NE}. The maximum V_{NE} used in design may be reduced only for a "ski configuration" airspeed limitation.

(5) Pads or "bear paws" installed on skid or wheel landing gear to facilitate operations in snow conditions or marsh lands may be approved as a part of or as an alteration to the aircraft type design. Rational flight and landing design loads applicable to the particular pad design must be developed and strength substantiating data submitted proving compliance with the strength and performance standards contained in Part 29. In addition, skid landing gear may be subject to excessive vibratory loads while in flight whenever the weight and mass distribution is altered by adding "bear paws." The effect of additional weight should be investigated over the flight operating regimes, including the approved range of rotor speeds. Resonant vibratory conditions should be avoided or highly damped, thus avoiding a potential change in service life. In compliance with § 29.571, Amendment 29-28, stress measurement, etc., may be necessary, if the standard is applicable.

SUBPART D - DESIGN AND CONSTRUCTION

FLOATS AND HULLS.

AC 29.751. § 29.751 (Amendment 29-3) MAIN FLOAT BUOYANCY.

a. Explanation.

(1) This section specifies standards for single and multiple float buoyancy in fresh water. The standard does not apply to ditching/emergency flotation devices, but to amphibian rotorcraft devices.

(2) It is a design and a performance standard. Rigid or inflatable floats may be used. Enough water tight compartments (per Amendment 29-3) rather than a specific number are required to minimize the probability of capsizing when one compartment is flooded or deflated.

b. Procedures.

(1) Excess buoyancy. A minimum of 50 or 60 percent in excess of the maximum certificated weight of the rotorcraft is required for single or multiple floats, respectively. The weight of fresh water (density 62.42 pounds per cu. ft.) displaced by fully submerged float or floats (total volume of each float at operating pressure is used) should be a minimum of 50 or 60 percent greater than the maximum certificated weight of the rotorcraft.

(2) Capsizing.

(i) Each float should have enough sealed, separate and approximately equal volume compartments to minimize the probability of capsizing when the critical compartment is flooded or deflated. Five or more compartments in each float are usually necessary to meet the standard. Ten compartments per float have been employed in certain designs.

(ii) An analysis or test or combination thereof may be used, if necessary, to prove a positive margin of stability with the most “critical” compartment in one float flooded or deflated.

(iii) The location of the floats, and the most critical compartment, the rotorcraft weight, mass moment of inertia, and center of gravity location are also important considerations for capsize stability.

AC 29.753. § 29.753 MAIN FLOAT DESIGN.

a. Explanation.

(1) Strength or design load standards are encompassed in the standard for inflatable bag and rigid floats. Bag pressure loads are included. The standard applies to an amphibious rotorcraft.

(2) The float landing loads are derived from the drop test of the float landing gear, or the load may be derived from tests of the wheel (or skid) landing gear (reference § 29.521). Bag type floats are not subject to the side loads according to the standard. Rigid floats, whether single or dual, are subject to the side load in each direction.

(3) Inflatable bag type floats should also be designed for the maximum pressure differential developed for the maximum operating altitude difference requested. That is, the resulting pressure difference between an operational altitude and a take-off site elevation should be established, and proven and may become an operating limitation.

(4) Landing loads suffice for the aerodynamic loads for typical rotorcraft float designs. Nonetheless, design and/or support of the forward part of bag type floats should be evaluated for maximum design speeds to prevent collapse or significant distortion of the bag while in flight.

(5) Resistance to puncture and abrasion at attach/wear points is not in the standard but is an important design consideration. "Girt" or attachment design loads shall be sufficient to withstand the loads imposed by the standards.

(6) The water or sea conditions (wave heights) evaluated in §§ 29.231 and 29.239 tests are not limitations but should be noted in the procedures section of the flight manual.

(7) The standard does not apply to ditching/emergency floatation devices.

b. <u>Procedures</u>.

(1) <u>Landing load factor</u>.

(i) A drop test of the float landing gear may be conducted to obtain the limit landing load factor (reference § 29.725). Level landing attitude should be used for the float assembly.

(ii) The limit load factor for wheel or skid landing gear may be used (reference § 29.521) for the floats.

(iii) The float design ultimate load factor is 1.5 multiplied by the limit load factor.

(2) Flight aerodynamic loads--bag type floats.

(i) Evaluate collapse or significant distortion of bag type floats for speeds up to V_D (1.11 V_{NE}) with the minimum operating bag pressure.

(ii) External tubes to support the bag may be employed.

NOTE: Design landing loads may exceed the flight loads.

(3) Altitude differential loads.

(i) Bag type floats should not rupture due to the change in absolute pressure from take-off to the operating altitude. The applicant should select and prove the maximum operating altitude differential desired. A 5,000 to 8,000 feet operating differential may be a sufficient limitation. That is the rotorcraft with bags properly inflated could not operate more than 5,000 to 8,000 feet above the take-off site elevation.

(ii) A proof and ultimate pressure test should be conducted for the design. If operating or inflation pressure is 2.62 PSI (including a tolerance) and 5,000 feet (pressure) differential is desired (use sea level to 5,000 feet pressures), the proof or limit pressure should be 2.62 + 2.47 = 5.09 PSI. The pressure relief valves may be set at this value also. The change in size during inflation should be recorded. Significant changes may adversely affect flight characteristics and should be evaluated. The ultimate or burst free pressure should be proof pressure (5.09 PSI) multiplied by 1.5 or 7.635 PSI. A video or photographic record may be used as a reference of the change in size or shape for this test.

(iii) Each compartment should be equipped with a pressure relief valve to further protect the bag from excessive internal pressure.

(iv) At least one float should be subjected to a burst pressure test. Record the gauge pressure of burst.

(4) Landing loads.

(i) Rigid float vertical and a combined vertical and aft load conditions. A vertical or up-load only and a vertical combined with an aft load component for a resulting vector angle of 14.03° from the vertical axis of the rotorcraft shall be used. Reference § 29.521(a). The resulting design load is the same load in both cases.

(ii) Rigid float side and vertical load condition. For each rigid float, whether single or dual, a vertical load combined with a side load resulting in a vector angle of 26.6° from the vertical axis of the rotorcraft shall be used. The side load is applied to each float individually. Both inward and outward acting side load conditions shall be substantiated separately for the design of dual floats.

(iii) Load distribution on rigid floats shall be appropriate for the critical conditions. ANC-3 or § 25.533 and FAR Part 25, Appendix B may be useful.

(iv) Bag type float. The loads and the distribution of the loads are rather simple according to the standards. Only vertical loads and vertical with aft (drag) component are specified in the standard. These shall be distributed along the length over 75 percent of the projected area of the bag. Side loads are not required.

(5) Operating limitations.

(i) V_{NE} with floats installed is typically lower than the V_{NE} for wheel or skid landing gear rotorcraft configurations.

(ii) Bag inflation pressure shall be placarded or stenciled near inflation fittings.

(iii) The operating attitude differential proven for bag floats shall be an operating limitation. In addition, the flight manual should caution pilots about the effect of a significant decrease in altitude from the take off level which causes or reduces pressure in the bag. Placards may be employed as well.

(iv) Flight test results may dictate a further reduction in V_{NE} or changes in other operating limitations.

AC 29.755. § 29.755 (Amendment 29-30) HULL BUOYANCY.

a. Explanation.

(1) This section contains performance standards for an integral fuselage hull and auxiliary (such as outrigger) floats. Water-based, amphibian and limited amphibian rotorcraft were encompassed in the standard.

(2) Amendment 29-3 added but Amendment 29-30 removed paragraph (b) which concerned Limited Amphibian Rotorcraft. Rotorcraft of that type used a “boat type hull” which is not desirable now and are certificated to the standards of § 29.801, Ditching, and § 29.563, Structural ditching provisions. (Limited amphibian rotorcraft were converted to the ditching configuration.)

(3) The worst combination of wave height and surface winds selected by the applicant shall be used in compliance with the standard.

b. Procedures.

(1) Capsizing.

(i) The hull and auxiliary floats shall have enough sealed compartments to allow failure of the critical, single, compartment in either the hull or auxiliary float and minimize the probability of capsizing.

(ii) Location of the most critical compartment (whether hull, sponson, or auxiliary), rotorcraft weight, mass moment of inertia, and CG location are also important considerations to prove stability or not capsizing.

(iii) The lightweight rotorcraft configuration and wind and wave condition should be considered, as well as the heavy weight configuration.

(iv) The sea state (worst combination of wave height and surface winds) is selected by the applicant. The condition proven is included in the procedures or information section of the flight manual. (It is not an operating limitation.)

(2) Buoyancy.

(i) Excess buoyancy is necessary to comply with the standard but the amount is dependent on several factors, such as number, size, and location of the sealed, watertight, compartments.

(ii) Wheel tires may be used for buoyancy if appropriate to the design.

(iii) Fuel tanks, if properly located and protected from potential rupture and if the aircraft has a system to rapidly empty the tanks, may be used also for buoyancy.

(iv) Buoyancy may be determined using the displacement of fresh water, with 62.42 pounds per cubic ft. density.

(3) Tests.

(i) If necessary, scale models may be used to prove the stability of the rotorcraft design for the sea state and wind conditions selected by the applicant.

(ii) The rotorcraft is subject to water tests per § 29.231. Compliance with part of this standard may be demonstrated or proven for the sea state or wave height, and wind conditions selected in conjunction with the TIA flight test program. This information is not an operating limitation.

(iii) Proposals should be submitted for evaluation.

AC 29.757. § 29.757 (Amendment 29-3) HULL AND AUXILIARY FLOAT STRENGTH.

a. Explanation. The standard is an objective or performance strength standard. The water loads in § 29.519 shall be imposed for the hull and auxiliary floats in a conservative manner. The hull and float are “rigid” conventional amphibian or water-based aircraft structures.

b. Procedures.

(1) The water loads and conditions specified in § 29.519 shall be used. The pressures or load distributions should be appropriate to the design. ANC-3 and §§ 25.523 through 25.535 and Appendix B to FAR Part 25 may be of use.

(2) The water loads and applications of the loads are objective standards. A proposal and early discussions in the life of a project should be used to agree on an appropriate avenue or means of compliance. Tests or analysis supported by tests may be appropriate.

SUBPART D - DESIGN AND CONSTRUCTION

PERSONNEL AND CARGO ACCOMMODATIONS

AC 29.771. § 29.771 (Amendment 29-24) PILOT COMPARTMENT.

a. Explanation.

(1) Volumes have been written on human factors and their contribution to pilot workload and fatigue. This document cannot begin to address the myriad of considerations involved in pilot compartment design. The intent of the rule is simply to ensure that reasonable human factor engineering practices have been followed. Equipment should be logically grouped within the pilot's reach and view and be easy to operate. Seats should provide a reasonable level of comfort for the normal anthropometric range of pilots for a typical mission duration. Environmental considerations such as radiation from the sun through overhead windows should be addressed. Heating, cooling, and ventilation systems should be adequate for the range of expected operating conditions.

(2) Each pilot compartment and its equipment should allow the minimum flightcrew to perform their duties without unreasonable concentration or fatigue. If there is a provision/requirement for a second pilot, his station should be equipped with primary flight controls and have easy access to powerplant controls. Duplicate wheel brakes are recommended. Duplication of miscellaneous controls such as idle detent switches, RPM beep functions, nosewheel locks, and parking brakes has not been required. The need for duplicate instruments for the second pilot tends to be a function of cockpit size and panel configuration.

(3) Webster defines appurtenances as "accessory objects or apparatus." Items such as blowers, fans, and gyros should not have noise or vibration characteristics which could contribute to pilot fatigue or distraction. Instrument panel vibration is specifically addressed in § 29.1321.

(4) Although the rule prohibits in-flight rain or snow leaks that distract the crew or harm the structure, leaks occurring on the ground should also meet these requirements. In extreme cases where an offensive leak could not be stopped, the moisture has been rerouted to a noncritical area. In the context of this rule, "structure" is interpreted to include any part of the pilot compartment to include systems and equipment.

b. Procedures.

(1) Initial evaluation of the pilot compartment should be conducted on the ground. However, the cockpit assessment should be an ongoing effort throughout the flight test program. If a second pilot position is provided/required, the adequacy of

controls and instruments should be evaluated under all normally expected operating conditions. If a second pilot position is not provided/required, any passenger position in the pilot compartment should be evaluated to ensure that a passenger, properly briefed by the flightcrew, can sit comfortably without inadvertent interference with normal control operations. All equipment should be operated during at least one flight of typical mission profile and duration.

(2) Although many pilot compartment rain or snow leaks can be located on the ground by dousing the aircraft with a hose, in-flight leaks often occur in varying intensity and in different locations. Flight in rain should therefore be included during flight test.

AC 29.773. § 29.773 (Amendment 29-3) PILOT COMPARTMENT VIEW.

a. Nonprecipitation Conditions.

(1) Explanation.

(i) The procedures paragraph following this explanation discusses one means of demonstrating an adequate field of view.

(ii) Since glare and reflection often differ with the sun's inclination, consideration should be given to evaluating the cockpit at midday and in early morning or late afternoon. Windshields with embedded wire heating elements should be evaluated for distortion with the system both “ON” and “OFF.”

(iii) If night approval is requested, all lighting, both internal and external, should be evaluated in likely combinations and under expected flight conditions. Although a certain amount of equipment reflection (avionics control heads, etc.) in the windscreen may be unavoidable, the pilot's normal field of view should be unobstructed. Windshield reflections often dictate large glareshields which result in reduction of the optimum field of view. This problem is most apparent in IFR equipped aircraft (having larger instrument panels and avionic consoles) which are operated in VFR utility roles. Landing and taxi lights should be exercised throughout their adjustment range (if applicable) to check for reflections, particularly in chin windows. Anticollision and strobe lights should be evaluated to ensure that frequency interaction and reflections off the rotor do not result in distractions to the pilot. The effect of cabin lighting on the pilot compartment view should be assessed, particularly on EMS configured aircraft where the in-flight use of cabin lights may be mandatory.

(2) Procedures. The following procedures are one acceptable means of evaluating pilot compartment field of view considering only those objects in the pilot compartment, the windshield, and its support structure in nonprecipitating conditions. The applicant's design is not required to meet these guidelines, and each design should be evaluated on its own merits. The area of visibility established in the following paragraphs will provide an acceptable level of visibility for a minimum crew of one (pilot). In the event that a minimum crew of two (pilot and copilot) is required, the

second pilot should have an area of visibility equivalent to that provided for the pilot but on the opposite side. In this event, the pilot's area of visibility to the left as shown in figure AC 29.733-1 needs only to comply to 60° left, and the area of visibility for the second pilot needs only to comply to 60° right.

(i) A single point established in accordance with the provisions of this paragraph constitutes the referenced eye position (i.e., a point midway between the two eyes) from which the central axis may be located. The referenced eye position is a reference datum point based on the eye location that permits the specified vision envelope required by figure AC 29.733-1, allows for posture slouch, and is the datum point from which the aircrew station geometry is constructed. The referenced eye position should be located by means of ship's coordinates that contain station reference number, water line, and butt line for both pilot and copilot, if applicable, and complies with:

(A) The pilot's seat in a normal operating position from which all controls can be utilized to their full travel, by an average subject, and which should provide for vertical adjustment of the seat of not less than 2.5 inches above and 2.5 inches below this initial vertical position.

(B) The seat back in its most upright position.

(C) The seat cushion depression being that caused by a subject weighing 170 to 200 pounds.

(D) The longitudinal axis of the rotorcraft to be that of "cruise attitude" ($0.9V_H$ or $0.9\ V_{NE}$ whichever is lower).

(E) The point established not beyond 1 inch to the right or left of the longitudinal centerline of the pilot's seat.

(F) All measurements made from the single point established in accordance with this paragraph.

(ii) A dual lens camera, as photo recorder, should be used in measuring the angles specified in the paragraphs listed below. Other methods, including the use of a goniometer, are acceptable if they produce equivalent areas to those obtained with a dual lens camera. When not using a dual lens camera, compensation should be made for one-half the distance which exists between the eyes, or 1¼ inches. With the referenced eye position located as indicated in paragraph AC 29.733a(2)(i), and utilizing binocular vision and azimuthal movement of the head and eyes about a radius, the center of which is 3 and 5/16 inches behind the referenced position (this point to be known as the central axis), the pilot should have the following minimum areas of vision measured from the appropriate eye position. (See figure AC 29.733-1.)

(A) 20° forward and above the horizon between 0° and 100° left.

(B) 20° forward and below the horizon between 10° and 100° left.

(C) 20° forward and below the horizon at 10° left increasing to a point 30° forward and below the horizon at 10° right.

(D) 50° forward and below the horizon between 10° right and 135° right.

(E) 20° forward and above the horizon at 0° increasing to a point 40° above the horizon at 80° right and 100° right and then decreasing to a point 20° forward and above the horizon at 135° right.

(iii) Any vertical obstruction which falls within the minimum area of visibility outlined in paragraph AC 29.733a(2)(ii) should be governed by the following:

(A) No vertical obstruction between 20° right and 20° left.

(B) Between 20° right and 135° right, vertical obstruction should not exceed 2.5 inches in width.

(C) Between 20° left and 100° left no vertical obstruction greater than 2.5 inches in width.

(iv) Any horizontal obstruction which falls within the minimum area of visibility outlined in paragraph AC 29.733a(2)(ii) should be governed by the following:

(A) The area 15° forward and above the horizon between 135° right and 40° left decreasing to a point 10° above the horizon at 100° left, and 15° forward and below the horizon between 135° right and 100° left should be free from horizontal obstructions.

(B) The area above and below the horizon which is between the minimum area of vision specified in paragraph AC 29.733a(2)(ii) and paragraph AC 29.733a(2)(iv)(A) is limited to one horizontal obstruction above the horizon, and one below the horizon. These horizontal obstructions should not be greater than 4 inches in width. An overhead window which will provide twice as much additional visibility as was lost due to the obstruction, should be located immediately above any obstruction which is above the horizon. This requirement is in addition to any area of visibility specified by paragraph AC 29.733a(2)(ii) which may be included in the overhead window area.

(C) If the instrument panel obstructs any required area between 10° left and 10° right below 20° forward and below the horizon, a window which affords triple equivalent additional visibility should be located immediately below and between the angles of 20° left and 20° right above 65° below the horizon.

(v) For steep rejected takeoffs and steep approaches such as used for oil rigs or confined heliports, the visibility should be such that the pilot can see the touchdown pad and sufficient additional area to the side and forward to provide both an accurate approach to the touchdown point as well as a satisfactory degree of depth perception. A 5-inch head movement, by the pilot, forward and/or sideward of the normal position is acceptable in determining compliance.

b. Precipitation Conditions.

(1) Explanation.

(i) Heavy rainfall is defined by the National Weather Service as one resulting in accumulation in excess of 0.03 inches in 6 minutes. On past designs, the windshield wipers required by § 29.1307 have been adequate to ensure satisfactory view at low to medium airspeeds. Airflow over the windshield and/or wipers has normally been sufficient to keep the windshield clear at higher airspeeds. Obscuration of side windows by rainfall should be addressed, particularly for confined area approaches.

(ii) If icing certification is requested, a means must be provided to ensure that a sufficiently large viewing area is kept clear of ice to permit safe operation. As a minimum, a clear area on the windshield should be available, although some configurations could require clear view in other areas, in order to provide an adequate level of safety in certain operations.

(iii) An openable "clear view" window must be provided for the first pilot. The rule requires that the window be openable in heavy rain at forward speeds to V_H and in the worst icing conditions requested for certification. The rule further requires a field of view through this opening which is adequate for safe operation. Although the rule implies that a safe field of view must be provided for airspeeds up to V_H, it has not been interpreted as such. In most designs, the only practical location for an openable window is in a side panel or door. Aircraft sideslip limits normally restrict useful view from this window opening at high airspeeds. The intent is to provide the pilot with an adequate view for safe approach and landing in the event that normal windshield clearing systems malfunction.

(2) Procedures. Compliance with the requirements of this rule should be checked by flying the aircraft in the applicable environmental conditions. Although wipers can be partially checked on the ground with a hose, their effectiveness at higher airspeeds should also be verified. Likewise, additional or alternate rain removal systems should be exercised throughout the required airspeed range. The need for windshield wash systems should be assessed, particularly if the aircraft will be used in an offshore salt spray environment. Systems provided to ensure clear view in icing conditions should be evaluated during icing flight tests. The location and effectiveness of the openable window should be evaluated following failure of the rain removal and anti-ice system (if applicable). The view through the window opening should permit

safe operation from hover up to a reasonable approach airspeed. Care should be exercised during flight test to stay within airframe sideslip limits.

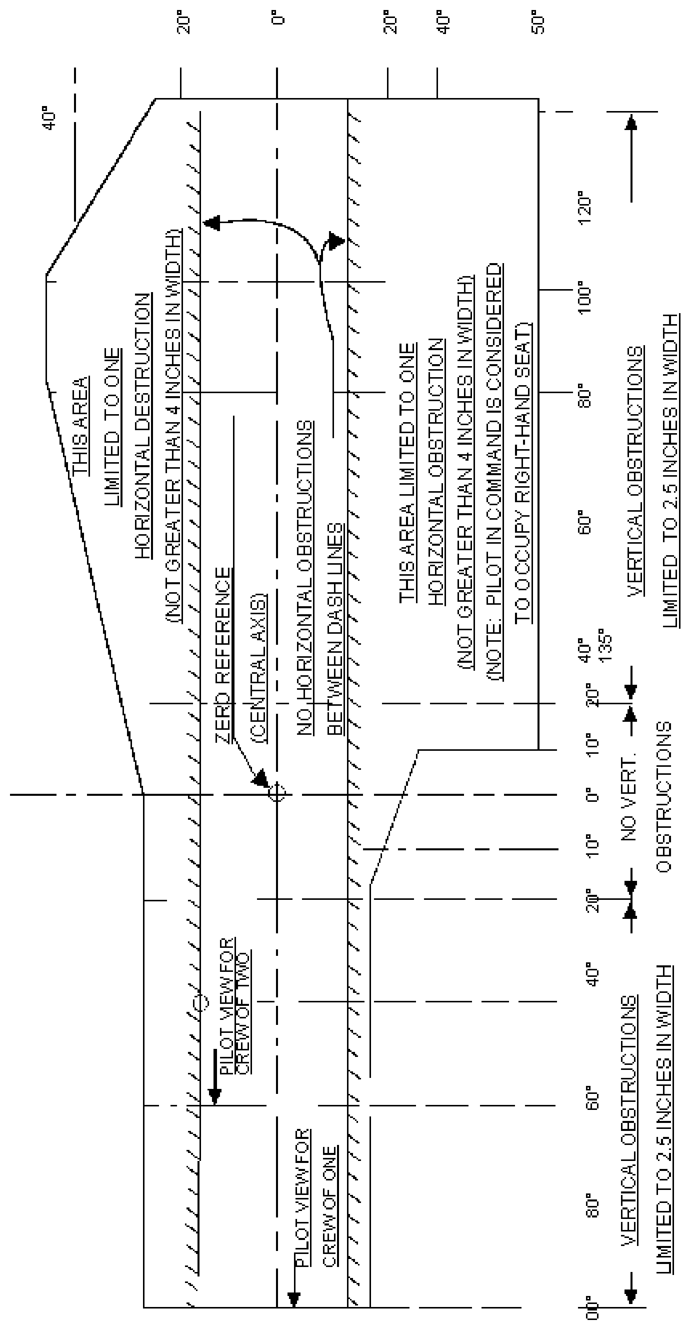

FIGURE AC 29.773-1 COCKPIT VISIBILITY

AC 29.775. <u>§ 29.775 WINDSHIELDS AND WINDOWS</u>.

a. <u>Explanation.</u> Nonsplintering safety glass is specified in windshields and windows containing glass to protect crew and passengers if window fracturing occurs. In any case, windshields and windows are to be made of transparent materials which will not break into dangerous fragments.

b. <u>Procedures</u>.

(1) Use nonsplintering safety glass in windshield or window applications which contain glass rather than plastic acrylics, polycarbonates, epoxies, etc. The glass selected should meet a specification such as MIL-G-25871, and if new vendors are selected by an airframe manufacturer, test data should be obtained from the vendor to demonstrate the safety glass provided meets an acceptable specification and provides adequate nonsplintering capability.

(2) Windshields and windows should be designed so that either --

(i) They are made of material which will not cause a serious reduction in the field of view by becoming suddenly opaque; or

(ii) Any one panel becoming opaque will not cause a serious reduction in the field of view (reference § 29.773).

(3) In the event of any reasonably probable failure, a transparency heating system must be incapable of raising the temperature of any windshield or window to a point where there would be a danger of fire or structural failure (reference § 29.1309).

AC 29.775A. <u>§ 29.775 (Amendment 29-31) WINDSHIELDS AND WINDOWS</u>.

a. <u>Explanation</u>. Amendment 29-31 changed § 29.775 to allow the use of material other than nonsplintering safety glass; i.e., plastics are allowed. Additionally, whatever material is used should not break into dangerous fragments upon impact.

b. <u>Procedures</u>. The procedures contained in paragraph AC 29.775 apply equally to glass or plastics.

AC 29.775B. <u>§ 29.775 (Amendment 29-40) WINDSHIELDS AND WINDOWS</u>.

a. <u>Explanation</u>. Amendment 29-40 added § 29.631 which requires the rotorcraft be designed to ensure capability of continued safe flight and landing (Category A) or safe landing (Category B) after impact with a 2.2 lb (1.0 kg) bird when the velocity of the rotorcraft (relative to the bird along the flight path of the rotorcraft) is equal to V_{NE} or V_H (whichever is lesser) at altitudes up to 8,000 feet.

b. Procedures. In addition to the procedures outlined above, compliance with § 29.631, should be demonstrated by tests or analysis supported by test evidence that the windshield will withstand, without penetration, the impact with a 2.2 lb (1.0 kg. bird) at V_{NE} or V_H (whichever is lesser) at altitudes up to 8,000 feet. See paragraph AC 29.631 (§ 29.631) for additional information.

AC 29.777. § 29.777 COCKPIT CONTROLS.

a. Explanation. This section defines the general cockpit control requirements. Cockpit control location and arrangement, with respect to the pilot's seat, must be designed to accommodate pilots from 5'2" to 6'0" in height.

b. Procedures.

(1) The applicant should have a cockpit design report which documents the anthropometric suitability of the cockpit. Subsequent cockpit evaluations of control movement and location should be conducted with adjustable seats and/or controls positioned in a flight position for the subject pilot. Essential controls should be evaluated with the shoulder harness locked in the retracted position. Evaluation pilots should be aware of their individual anthropometric measurements and temper their assessments based on this information. Ideally, a new design should include evaluations by a range of different sized subject pilots. Control considerations for a second pilot position are the same as for the pilot station. Paragraph AC 29.771 discusses current philosophy concerning duplication of controls.

(2) As background, the following are examples of cockpit control issues which should be avoided:

(i) Collective control blocking the lateral movement of a pilot's leg, which in turn restricts the left lateral cyclic displacement.

(ii) Seat or seat cushion impeding the aft cyclic movement.

(iii) Inadequate space for large feet equipped with large flight boots.

(iv) Control/seat relationship which requires unusual pilot contortions at extreme control displacements.

(v) Control/seat relationship or control system geometry which will not permit adequate mechanical advantage with unboosted controls or in a boost OFF situation.

(vi) Addition of control panels or equipment to instrument panels or consoles which restrict full control throw.

(vii) Brake pedal geometry which results in inadvertent brake application upon displacement of the directional controls.

(viii) Controls for accessories or equipment which require a two-handed operation.

(ix) Emergency external cargo release controls which cannot be activated without releasing the primary flight controls.

(x) Essential controls which cannot be actuated during emergency conditions with the shoulder harness locked.

(xi) Throttle controls which can be inadvertently moved through idle to the cutoff position.

(xii) Switches, buttons, or other controls which can be inadvertently activated during routine cockpit activity including cockpit entry.

(xiii) Failure to account for operation with the pilot wearing bulky winter clothing.

(xiv) Aft cyclic movement limited by the pilot's body with a fore and aft adjustable seat in the full forward position.

AC 29.779. § 29.779 (Amendment 29-24) MOTION AND EFFECT OF COCKPIT CONTROLS.

a. Explanation. The section standardizes motion and effect of cockpit controls. While this paragraph specifically addresses primary flight controls, engine power controls, and landing gear controls, it applies to all cockpit controls not addressed in other paragraphs.

b. Procedures.

(1) The cyclic should be mechanized such that movement of the control results in a corresponding sense of aircraft motion in the same axis. While a certain amount of coupling may be present following a pure control input in a given axis, that coupling should not be objectionable to the pilot. Collective pitch control should be mechanized such that an upward movement of the collective results in a corresponding relative motion of the aircraft in the vertical plane. Again, coupling should not be objectionable. Care should be taken to ensure that the primary pilot perception of collective motion is in the vertical plane. The objective is to clearly differentiate collective motion from that associated with an airplane throttle. The rule is self-explanatory on the subject of engine power controls. A distinction is made between normal landing gear controls and emergency controls. Emergency controls may operate in a sense which might not correspond to the direction of resultant gear motion.

(2) The recommended operating convention and “switchology” for miscellaneous controls is:

(i) Up/forward = on/increase.

(ii) Down/aft = off/decrease.

(iii) Variable rotary controls should move clockwise from the OFF position, through an increasing range, to the full ON position. For some variable intensity controls such as instrument lighting, the desired minimum setting may not be completely off. Pushbuttons not giving an obvious indication of mechanical position should be configured such that the flightcrew has a clear indication of switch actuation under both day and night (if applicable) conditions. Failure of the indication should be shown to be free of hazards.

(3) Slew or “beep” switches associated with flight control system applications warrant special attention. The recommended conventions for control-mounted single, or multifunction, two or four-way “beep” switches are:

(i) <u>Cyclic</u>.

<u>Switch Direction</u>	Flight Control System <u>/Autopilot Configuration</u>	<u>Aircraft Response</u>
Forward/up	basic trim	nose down
	airspeed/groundspeed mode selected	increased airspeed forward speed reference
	vertical speed mode selected (without airspeed mode engaged)	increased rate of descent/decreased rate of climb
	hover mode selected	increased ground-speed or forward acceleration reference
Left	basic trim	left wing down
	heading mode selected	slew heading reference left
	hover mode selected	increased ground-speed or acceleration reference to left

(ii) Collective (assumes switch is mounted on top of grip).

Switch Direction	Flight Control System /Autopilot Configuration	Aircraft Response
Forward	control position hold	down collective
	vertical speed mode selected	increased rate of descent/decreased rate of climb
	hover mode selected	decreased hover height reference
Left	control position hold	increase left pedal
	hover mode selected	slew heading reference left

(iii) Opinions are divided concerning the preferred convention for forward and rearward motion of slew switches mounted atop the collective grip. Part of the reason appears to stem from the fact that such a switch is never used in a purely control position trim capacity. The switch has normally remained nonfunctional until a vertical autopilot mode is selected. At that point, the switch is viewed by one pilot/engineer contingent as either an autopilot reference slew function or a power increase/decrease switch, which should follow the "forward equals increase" convention. The other group views the switch as a form of control position trim and finds the "forward equals down collective" convention to be more consistent with the sensing used for the cyclic beep switches. An obvious solution is to mount collective/vertical axis switches in a vertical orientation on the grip. Barring that alternative, viable arguments can be made for either philosophy. The recommended convention was selected following a survey of manufacturers and test pilots.

AC 29.783. § 29.783 (Amendment 29-20) DOORS.

a. Explanation. This regulation requires at least one door for all closed cabin rotorcraft. Standards for all doors and airstair doors are included. To assure that the doors provide normal entry and egress without causing or contributing to hazardous conditions, even after a minor crash, the following requirements are imposed:

(1) Passenger doors may not be located with respect to any rotor to endanger persons using the doors as instructed.

(2) Means are required for locking crew and external passenger doors to prevent their opening in flight due--

(i) To inadvertent operation; or

(ii) To mechanical failure.

(3) External doors are required to be openable from the inside or outside by simple and obvious means.

(4) Reasonable provisions to prevent jamming of external doors are required as specified and to assure that an “airstair door” is useable.

(5) The following visual indications of external doors being closed and locked are required:

(i) Direct visual inspection means by crewmembers of the locking mechanism of all external doors.

(ii) Visual means to signal to crewmembers “when normally used external doors are closed and fully locked.”

(6) For certain outward opening doors, an auxiliary safety latching device is required “to prevent the door from opening when the primary latching mechanism fails.” Suitable operating procedures to prevent this device from being used during takeoff and landing are required if the door cannot be opened from outside the rotorcraft (reference § 29.783(c)) with the device in place.

b. Procedures.

(1) Passenger doors should be located as far as possible from the auxiliary rotors. The doors may be hinged and door open stops may be provided to separate entering and egressing passengers from the auxiliary rotor blades. If necessary for the design, “appropriate instructions” should be provided for all passenger doors concerning entering and leaving the rotorcraft and safe use of each door relative to all rotors. These instructions should be obvious to a passenger using the door, contain large enough letters to be readily legible, and use letters or background colors associated with danger (i.e. orange or red).

(2) Means to prevent the opening of doors in flight.

(i) Means to prevent the opening of doors in flight due to inadvertent operation may be provided by recessing door handles to prevent their inadvertent operation by the normal movement of passengers about the cabin. If recessing the door handle is impractical, a cover may be provided which will prevent inadvertent operation of the handle, but the cover should be of such design that it does not obscure the door handle or its operating instructions. It must not unduly interfere with deliberate operation of the door handle by passenger or crew. Transparent or nonsolid covers, easily displaced by deliberate actions, have been used to prevent inadvertent door handle operation. Some rotorcraft designs meet this requirement by requiring that passengers wear their seat belts at all times during flight. This design requires that the “fasten seat belt” sign be on at all times the rotorcraft is in flight (for practical purposes, the “fasten seat belt” light is generally designed to be on when power is applied to the rotorcraft).

(ii) Means to prevent inadvertent door opening in flight due to “mechanical failure” is most efficiently provided by multiple door latches and multiple load path door locking mechanisms so that the door will remain locked after a single failure. Care should be taken in the design of multiple load path latches and mechanisms to assure independence of all failures and to consider the effort of deflections after failures (if a failure allows deflections into the airstream sufficient to increase aerodynamic loads, the increase in loads should be accounted for; if a failure allows significant movement of latching components, the deflections should be accurately accounted for to assure that disengagement of nonfailed latches does not occur).

(3) The means to open normally used external doors is required to be simple (such as a rotating handle) and to be accessible from the inside or the outside. To prevent the inadvertent use of emergency exits (separate from normal entry doors) for routine entry and exit with the resulting “wear and tear,” the normally used doors for entry and exits should be equipped with operating handles and instructions distinctly different from those of the emergency exits. Obviously, the above does not apply to normally used exits which are also the primary (or only) emergency exits.

(4) <u>Reasonable</u> provisions to prevent jamming of external doors include the following:

(i) Design features of doors which are insensitive to large fuselage deflections for door operation.

(ii) Provision of clearance between door and door frame latching devices sufficient to allow some relative deflection between the door and door frame and still allow door operation. The relative deflections may be determined by static test or by an analysis approved by the FAA/AUTHORITY.

(iii) Sliding doors are frequently used in transport rotorcraft for versatility and utility reasons. If sliding doors are used, one of the following features of design may be required to assure that the requirements of § 29.783(d) are met:

(A) The sliding door(s) must be provided with jettison features which allow release of the door(s) from the tracks (to preclude jamming). The emergency release is generally separate and distinct from the normal door handle.

(B) Separate emergency exits of appropriate size and number may be installed in the sliding door(s).

(C) Separate emergency exits of appropriate size and number may be installed <u>in addition to</u> the sliding door(s).

(iv) Whether or not the sliding door is qualified as an <u>emergency exit</u>, it must meet the remaining <u>door</u> design standards.

(5) Direct visual inspection means by crewmembers of the locking mechanism of external doors may provide for visual observation of the door frame and the latching components for engagement or for visual observation of "flag" areas of the locking mechanism. If "flag" areas are used (such as tabs or shoulders which protrude into the crewmember's line of sight when the latches are engaged (locked)), care should be taken to assure that the tab is permanently affixed (or an integral part) to the locking mechanism; and it should not give erroneous readings to the crewmembers under any foreseeable operation or failure of the latching mechanism. "Visual means to signal" to crewmembers "when normally used external doors are closed and fully locked" may be provided by annunciator panel lights or equivalent means. The visual indicating system may consist of an indicator for each individual door, or a system connecting all doors in series. If the latter system is used, it need not necessarily show which door is not fully locked. It is not necessary that more than one crewmember be able to ascertain by a visual signal that all external doors normally used by the crew in supplying the rotorcraft, or in loading and unloading passengers and cargo, are fully closed and locked. The visual signal should be located so that it may easily be seen by the appropriate crewmember from his station.

(6) For § 29.783(f), the auxiliary safety latching device to "prevent the door from opening when the primary latching mechanism fails" can be provided by the same multiple load path features which meet the § 29.783(c) requirement for prevention of door opening in flight after a "mechanical failure." If a completely separate "auxiliary safety latching device" is used, it should allow the door to be opened from the inside, or outside, when in place. If the device must be removed to allow use of the door, "suitable operating procedures" (i.e., placards and RFM instructions) will be required for removal of the device during takeoff and landing.

(7) Additional standards for "airstair doors" were added by Amendment 29-20.

(i) An analysis or test may be used to prove compliance with deformation standards in § 29.783(g)(1).

(ii) A sketch, drawing, or demonstration may be used to prove the door is useable for the conditions described in § 29.783(g)(2).

AC 29.783A. § 29.783 (Amendment 29-31) DOORS.

a. Explanation.

(1) Amendment 29-30 extends the requirements of § 29.783 to:

- include each external door, not just passenger doors; and,

- require provision of door location and/or door operation procedures to protect persons from danger from propellers, engine intakes, and engine exhausts. (Protection from rotors are already included in the standard.)

(2) Amendment 29-31 adds a new paragraph (h) to § 29.783 which requires for doors used for ditching egress to have a means to secure the "ditching exits" in an open position and remain securely open in the appropriate Sea State used for compliance with § 29.801, paragraph AC 29.801.

b. Procedures. The procedures of paragraph AC 29.783 continue to apply to § 29.783 (and Amendment 29-31) with the following additions:

(1) Occupants of the rotorcraft and servicing personnel are now required to be protected from injury when using any external door to enter or egress the rotorcraft and when loading cargo or servicing the rotorcraft. Consideration should be given to door location and/or operating procedures to include protection from propellers (if equipped) and engine inlets and exhausts, as well as from rotors.

(2) These new standards clarify that engine exhausts, engine inlets, and propellers, as well as rotors, are potentially hazardous and should be located or designed to protect rotorcraft occupants and ground personnel or use door latching and operating procedures to protect those persons. Operating procedures for the door, including readily visible markings, should be provided to minimize injury to personnel when practical component locations or component design features, alone, do not assure possible freedom from injury.

(3) For § 29.783(h), a means such as a cable, chain, pin, or mechanical linkage should be provided to secure doors used as ditching exits in the open position. The means should be shown to be effective under rotorcraft attitudes and dynamic conditions common to ditching. The sea states for ditching approval in accordance with § 29.801 are found in paragraph AC 29.801. Demonstrations under actual ditching conditions are not mandated for substantiation purposes, but the substantiation methodology should be reliable, i.e., an analytical or test method demonstrated to be reliable and used in previous structural substantiation programs.

AC 29.785. <u>§ 29.785 SEATS, SAFETY BELTS, AND HARNESSES</u>.

a. <u>Explanation</u>.

(1) This section requires that seats, belts, harnesses, and adjacent parts of the rotorcraft be substantiated for the structural loads resulting from the inertia forces of § 29.561 as well as normal flight and ground inertia forces on a 170-pound occupant. The inertia forces of § 29.561 are ultimate lo0ads and must be multiplied by a factor of 1.33 in determining the "strength of attachment" of each seat to structure and each belt or harness to structure. The seat, belt, etc., are required to sustain applied loads and to protect the occupant from serious injury. The pilot seats must also sustain the effects of the pilot forces of § 29.397.

(2) In addition, the "occupant must be protected from head injury" by the seat belt and one of the following:

(i) A harness to prevent the head from contacting an injurious object.

(ii) Elimination of injurious object within striking distance of the head.

(iii) A cushioned rest as specified.

(3) Handholds are required to steady occupants using the aisle in moderately rough air.

(4) Projecting objects which would injure occupants "in normal flight must be padded."

b. <u>Procedures</u>.

(1) Each seat with its belts and harnesses are to be substantiated for the flight, ground, and emergency landing loads of § 29.561 by structural test or stress analysis. Section 29.785(b) states that "each seat must be approved." Certification approval can be gained by Technical Standard Order (TSO) approval or by accomplishing sufficient structural substantiation to gain FAA/AUTHORITY approval of the seat and its belt(s) as part of the Type Design of the rotorcraft. TSO No. C-39 concerns standards for aircraft seats, including rotorcraft seats. If TSO No. C-39 is used as an approval basis for a specific rotorcraft seat, the seat should be checked to assure it has been substantiated for the vertical (up and down) and side loads imposed by installation in the aircraft. For example, TSO No. C-39 (and NAS 809) specifies an ultimate down load of 4.0g which is in agreement with the 4.0g emergency landing load factor of § 29.561, but it may be less than the design maneuver load factor (which can be as high as 3.5g limit or 5.25g ultimate).

(i) The 1.33 factor is specified for substantiation of attachments of each seat to the structure and each safety belt or harness to the seat or structure for § 29.561 loads, whether analysis or test is used.

(ii) If static testing of seats, belts, and harnesses is used, the body block of NAS 809 may be used. The corners of the NAS 809 body block may be radiused and padded if it is found that the small radii cause premature, unrealistic crippling of thin wall tubing or other structure used in the seat.

(iii) The substantiation of the pilot seats is required to include pilot forces of § 29.397 in conjunction with normal flight and ground loads. For example, the pilot foot force (195 pounds ultimate) must be reacted by the seat.

(2) The following criteria have been found satisfactory for preventing occupant head injuries:

(i) If a harness is used, it should support the shoulders without applying hazardous loads to the side or front of the neck. It should be easily donned and a single point release with the seat belt is preferred. If separate release is provided, it must be simple, compatible with the seat belt release, and near the seat belt release. The harness should be tested in conjunction with the seat belt using a “body block” similar to that of NAS 809 if possible. If the harness is tested separately from the belt, it should be tested to 50 percent of the forward crash loads for the entire occupant weight of 170 pounds, unless that percentage distribution is found to be unrealistic by a rational analysis.

(ii) Elimination of injurious objects within striking distance of the head and other vital parts can be accomplished by removal of objects with sharp edges or rigid surfaces from within striking distance of vital parts of the occupant. Dimensions and weights for typical occupants are available in U.S. Army USAAULABS Reports 70-22 (August 1969) and 66-39 (June 1966) and NACA Report TN 2991 (August 1953). Because of the range of occupant head striking distance, a combination of “elimination of injurious objects” and “cushioned rests” may be required for some interior configurations.

(iii) An acceptable cushioned rest can be provided by use of a 1-inch thickness of foamed polyvinyl chloride (PVC), or equivalent energy absorbing material. The density of material should be in the 5 to 10 pounds per cubic foot density range. PVC foam has the property of <u>absorbing energy</u> efficiently with negligible rebond effects. PVC foam recovers slowly to the original configuration after deformation. If PVC foam is used, however, care must be taken in its application relative to its flammability characteristics (reference § 29.853).

(3) Handholds for the occupants are generally provided by seat backs adjacent to the aisle. If the seat backs fold, the amount of support provided by the seat backs before they fold must be evaluated in a furnished interior or mock up. To provide

adequate support, the seat back may use an easily disengaged latch or adequate friction in the hinge mechanism to obtain adequate support. Handholds along the aisle are, of course, not needed for rotorcraft with no aisles or where seat belts must be fastened during flight.

(4) Projecting objects which could injure occupants in normal flight should be padded. The amount of padding required depends on the location, size, and minimum radius of the projecting object. In general, this requirement will mean that sharp edges must be padded with one-half inch of PVC foam or equivalent (5 to 10 lbs. density), while objects with radii in excess of 1 inch may meet the requirements of § 29.785(e) with a lesser amount of energy absorbing padding, if it can be contacted only by persons "moving about in the rotorcraft in normal flight."

AC 29.785A. § 29.785 (Amendment 29-29) SEATS, BERTHS, BELTS, SAFETY BELTS, AND HARNESSES.

a. Explanation. Amendment 29-29 makes the following changes to § 29.785:

(1) The title of § 29.785 now includes berths (which would include litters).

(2) Section 29.785(a) has been revised to include reference to the new § 29.562, "Emergency Landing Dynamic Conditions."

(3) Section 29.785(b) has been revised to include a reference to the new § 29.562(c)(5) head injury criteria and to describe a torso restraint system that is contained in TSO-C114.

(4) Section 29.785(f) has been revised to change the percentage of load distribution for safety belt and harness combination to 60-40.

(5) A new § 29.785(i) has been added which provides a list of "seating device system" components.

(6) A new § 29.785(j) provides for deformations of the seat energy absorption device system installed to meet the requirements of § 29.562 but requires that the system "remain intact and not interfere with rapid evacuation of the rotorcraft." Further "structural" performance standards are contained in §§ 29.562(c)(1) and (2). AC 20-137 also contains information.

(7) A new § 29.785(k) provides static strength and restraint requirements for litters and berths. Litters may be oriented laterally as well as longitudinally in the rotorcraft. Dynamic tests of litters are not required. For longitudinally oriented litters, features should be provided to protect the occupant from the increased loads in § 29.561(b) of Amendment 29-29.

b. Procedures. The procedures of paragraph AC 29.785 still apply to static substantiation of the seats, berths, safety belts, and harness. In addition:

(1) Compliance with § 29.562 (except litters are not included) and § 29.561(b) is required.

(2) Section 29.562 includes a specific pass fail criteria, which includes head injury criteria, (reference AC 20-137).

(3) Shoulder harnesses need only be substantiated for 40 percent of total occupant load rather than the former 60 percent adopted by Amendment 29-24.

(4) AC 20-137 provides guidance for evaluating the functioning of a seating energy absorption device system under dynamic test conditions. Stroking is associated with the vertical-horizontal impact case and is recognized in the static strength substantiation.

(5) Berths or litters installed within 15° or less of the rotorcraft longitudinal axis (oriented longitudinally) shall use a combination of restraint devices, such as are required to be equipped with a padded end-board, cloth diaphragm, or equivalent means to withstand and distribute the occupant loads resulting from § 29.561(b) requirements. Other berths or litters may be equipped with straps or safety belts to withstand the forward reaction of § 29.561(b) as well as other loads, including flight loads.

(i) Berths/litters may be substantiated by static load tests, analysis, or a combination thereof and need not be substantiated to the 1.33 fitting factor of seat installations.

(ii) The berth/litter occupant's head, neck, and spine should be protected from (landing) impact forward loads by appropriate design means; e.g.,

- non-longitudinal orientation of the berth/litter; or
- "feet forward" orientation; or
- distribution of an appropriate percentage of forward loads on the shoulders (not solely to the head and spine).

(iii) Recommendations for litter occupants:

- If the occupant's head is oriented forward, a shoulder harness should be provided, in conjunction with body and leg straps that prevents the occupant's head from falling off the litter. A padded end board, diaphragm, etc., may be used, provided head and spinal loads are alleviated or prevented.

- If the occupant's feet are oriented forward, the padded end board may also be used in combination with the body and leg straps or other such restraints.

- Multiple or combinations of devices should be used to distribute the occupant loads as well as protect the occupant from possible neck and spine compression.

AC 29.787. <u>§ 29.787 (Amendment 29-12) CARGO AND BAGGAGE COMPARTMENTS</u>.

a. <u>Explanation</u>.

(1) This section requires that cargo and baggage compartments be designed for normal flight and ground loads and for a 4g ultimate forward load condition. Maximum placarded weights and critical distributions are to be considered.

(2) Means to prevent cargo shifting and contact between any cargo lamp bulb and cargo is to be provided.

b. <u>Procedures</u>. Structure tests or analyses may be used for substantiation for the design loads.

(1) Nets or straps may be used to prevent cargo shifting. The nets or straps are required to be substantiated for the structural loads. They need a means for adjustment to assure proper restraint for different sizes and shapes of cargo.

(2) Cargo lamp bulbs need to be guarded, recessed, or placed in upper inside corners to prevent contact with cargo.

AC 29.787A. <u>§ 29.787 (Amendment 29-31) CARGO AND BAGGAGE COMPARTMENTS</u>.

a. <u>Explanation</u>. Amendment 29-31 adds two subparagraphs to § 29.787 (c) which clarify that cargo and baggage compartments should be designed to protect occupants from injury by the compartment contents during emergency landings. This may be done by <u>location</u> or by <u>retention provisions</u>. The new paragraphs also add a requirement that the compartment contents should not cause injury when subjected to the loads of § 29.561.

b. <u>Procedures</u>. The procedures of paragraph AC 29.787 are still applicable. In addition to the forward load, the cargo and baggage compartments should be designed to withstand loads in other directions as specified in § 29.561. Also, the compartment may be shown to provide protection of occupants by location; i.e., cargo and baggage compartments may be shown to be <u>located</u> in a position where loose contents will not endanger occupants in an emergency landing. If the compartment is located above or behind the occupied area, § 29.561(c) still applies. If a compartment is in the occupied area, § 29.561(b) may apply.

AC 29.801. § 29.801 (Amendment 29-12) DITCHING.

a. Explanation.

(1) Ditching certification is accomplished only if requested by the applicant.

(2) Ditching may be defined as an emergency landing on the water, deliberately executed, with the intent of abandoning the rotorcraft as soon as practical. The rotorcraft is assumed to be intact prior to water entry with all controls and essential systems, except engines, functioning properly.

(3) The regulation requires demonstration of the flotation and trim requirements under "reasonably probable water conditions." The FAA/AUTHORITY has determined that a sea state 4 is representative of reasonably probable water conditions to be encountered. Therefore, demonstration of compliance with the ditching requirements for at least sea state 4 water conditions is considered to satisfy the reasonably probable requirement.

(4) A sea state 4 is defined as a moderate sea with significant wave heights of 4 to 8 feet with a height-to-length ratio of:

(i) 1:12.5 for Category A rotorcraft.

(ii) 1:10 for Category B rotorcraft with Category A engine isolation.

(iii) 1:8 for Category B rotorcraft.

The source of the sea state definition is the World Meteorological Organization (WMO) Table. (See figure AC 29.801-1.)

(5) Ditching certification encompasses four primary areas of concern: rotorcraft water entry, rotorcraft flotation and trim, occupant egress, and occupant survival.

(6) The rule requires that after ditching in reasonably probable water conditions, the flotation time and trim of the rotorcraft will allow the occupants to leave the rotorcraft and enter liferafts. This means that the rotorcraft should remain sufficiently upright and in adequate trim to permit safe and orderly evacuation of all personnel.

(7) For a rotorcraft to be certified for ditching, emergency exits must be provided which will meet the requirements of § 29.807(d).

(8) The safety and ditching equipment requirements are addressed in §§ 29.1411, 29.1415, and 29.1561 and specified in the operating rules (Parts 91, 121, 127, and 135). As used in § 29.1415, the term ditching equipment would more properly be described as occupant water survival equipment. Ditching equipment is required for extended overwater operations (more than 50 nautical miles from the nearest shoreline and more than 50 nautical miles from an offshore heliport structure). However, ditching certification should be accomplished with the maximum required quantity of ditching equipment regardless of possible operational use.

(9) Current practices allow wide latitude in the design of cabin interiors and consequently, the stowage provisions for safety and ditching equipment. Rotorcraft manufacturers may deliver aircraft with unfinished (green) interiors that are to be completed by the purchaser or modifier. These various “configurations” present problems for certifying the rotorcraft for ditching.

(i) In the past, “segmented” certification has been permitted to accommodate this practice. That is, the rotorcraft manufacturer shows compliance with the flotation time, trim, and emergency exit requirements while the purchaser or modifier shows compliance with the equipment provisions and egress requirements with the completed interior. This procedure requires close cooperation and coordination between the manufacturer, purchaser or modifier, and the FAA/AUTHORITY.

(ii) The rotorcraft manufacturer may elect to establish a “token” interior for ditching certification. This interior may subsequently be modified by a supplemental type certificate or a field approval. Compliance with the ditching requirements should be reviewed after any interior configuration and limitations changes where applicable.

(iii) The Rotorcraft Flight Manual and supplements deserve special attention if a “segmented” certification procedure is pursued.

b. <u>Procedures</u>. The following guidance criteria has been derived from past FAA/AUTHORITY certification policy and experience. Demonstration of compliance to other criteria may produce acceptable results if adequately justified by rational analysis. Model tests of the appropriate ditching configuration may be conducted to demonstrate satisfactory water entry and flotation and trim characteristics where satisfactory correlation between model testing and flight testing has been established. Model tests and other data from rotorcraft of similar configurations may be used to satisfy the ditching requirements where appropriate.

(1) <u>Water entry</u>.

(i) Tests should be conducted to establish procedures and techniques to be used for water entry. These tests should include determination of optimum pitch attitude and forward velocity for ditching in a calm sea as well as entry procedures for the highest sea state to be demonstrated (e.g., the recommended part of the wave on which to land). Procedures for all engines operating, one engine inoperative, and all engines inoperative conditions should be established. However, only the procedures for the most critical condition (usually all engines inoperative) need to be verified by water entry tests.

(ii) The ditching structural design consideration should be based on water impact with a rotor lift of not more than two-thirds of the maximum design weight acting through the center of gravity under the following conditions:

(A) For entry into a calm sea--

(1) The optimum pitch attitude as determined in 337(b)(1)(i) with consideration for pitch attitude variations that would reasonably be expected to occur in service;

(2) Forward speeds from zero up to the speed defining the knee of the height-velocity (HV) diagram;

(3) Vertical descent velocity of 5 feet per second; and

(4) Yaw attitudes up to 15°.

(B) For entry into the maximum demonstrated sea state--

(1) The optimum pitch attitude and entry procedure as established in (b)(1)(i);

(2) The forward speed defined by the knee of the HV diagram reduced by the wind speed associated with each applicable sea state;

(3) Vertical descent velocity of 5 feet per second; and

(4) Yaw attitudes up to 15°.

(C) The float system attachment hardware should be shown to be structurally adequate to withstand water loads during water entry when both deflated and stowed and fully inflated (unless in-flight inflation is prohibited). Water entry conditions should correspond to those established in paragraphs AC 29.801(b)(1)(ii)(A) and (B). The appropriate vertical loads and drag loads determined from water entry conditions (or as limited by flight manual procedures) should be addressed. The effects of the vertical loads and the drag loads may be considered separately for the analysis.

(D) Probable damage due to water impact to the airframe/hull should be considered during the water entry evaluations; i.e., failure of windows, doors, skins, panels, etc.

(2) Flotation Systems.

(i) Normally inflated. Fixed flotation systems intended for emergency ditching use only and not for amphibian or limited amphibian duty should be evaluated for:

(A) Structural integrity when subjected to:

(1) Air loads throughout the approved flight envelope with floats installed;

(2) Water loads during water entry; and

(3) Water loads after water entry at speeds likely to be experienced after water impact.

(B) Rotorcraft handling qualities throughout the approved flight envelope with floats installed.

(ii) Normally deflated. Emergency flotation systems which are normally stowed in a deflated condition and inflated either in flight or after water contact during an emergency ditching should be evaluated for:

(A) Inflation. The float activation means may be either fully automatic or manual with a means to verify primary actuation system integrity prior to each flight. If manually inflated, the float activation switch should be on one of the primary flight controls and should be safeguarded against spontaneous or inadvertent actuation for all flight conditions.

(1) The inflation system design should minimize the probability of the floats not inflating properly or inflating asymmetrically. This may be accomplished by use of a single inflation agent container or multiple container system interconnected together. Redundant inflation activation systems will also normally be required. If the primary actuation system is electrical, a mechanical backup actuation system will usually provide the necessary reliability. A secondary electrical actuation system may also be acceptable if adequate electrical system independence and reliability can be documented.

(2) The inflation system should be safeguarded against spontaneous or inadvertent actuation for all flight conditions. It should be demonstrated that float inflation at any flight condition within the approved operating envelope will not result in a hazardous condition unless the safeguarding system is shown to be extremely reliable. One safeguarding method that has been successfully used on previous certification programs is to provide a separate float system arming circuit which must be activated before inflation can be initiated.

(3) The maximum airspeeds for intentional in-flight actuation of the float system and for flight with the floats inflated should be established as limitations in the RFM unless in-flight actuation is prohibited by the RFM.

(4) The inflation time from actuation to neutral buoyancy should be short enough to prevent the rotorcraft from becoming more than partially submerged assuming actuation upon water contact.

(5) A means should be provided for checking the pressure of the gas storage cylinders prior to takeoff. A table of acceptable gas cylinder pressure variation with ambient temperature and altitude (if applicable) should be provided.

(6) A means should be provided to minimize the possibility of overinflation of the float bags under any reasonably probable actuation conditions.

(7) The ability of the floats to inflate without puncture when subjected to actual water pressures should be substantiated. A full-scale rotorcraft immersion demonstration in a calm body of water is one acceptable method of substantiation. Other methods of substantiation may be acceptable depending upon the particular design of the flotation system.

(B) Structural Integrity. The flotation bags should be evaluated for loads resulting from:

(1) Airloads during inflation and fully inflated for the most critical flight conditions and water loads with fully inflated floats during water impact for the water entry conditions established under paragraph AC 29.801(b)(1)(ii) for rotorcraft desiring float deployment before water entry; or

(2) Water loads during inflation after water entry.

(C) Handling Qualities. Rotorcraft handling qualities should be verified to comply with the applicable regulations throughout the approved operating envelopes for:

(1) The deflated and stowed condition;

(2) The fully inflated condition; and

(3) The in-flight inflation condition.

(3) Flotation and Trim. The flotation and trim characteristics should be investigated for a range of a sea states from zero to the maximum selected by the applicant and should be satisfactory in waves having height/length ratios of 1:12.5 for Category A rotorcraft, 1:10 for Category B rotorcraft with Category A engine isolation, and 1:8 for Category B rotorcraft.

(i) Flotation and trim characteristics should be demonstrated to be satisfactory to at least sea state 4 conditions.

(ii) Flotation tests should be investigated at the most critical rotorcraft loading condition.

(iii) Flotation time and trim requirements should be evaluated with a simulated, ruptured deflation of the most critical float compartment. Flotation characteristics should be satisfactory in this degraded mode to at least sea state 2 conditions.

(iv) A sea anchor or similar device should not be used when demonstrating compliance with the flotation and trim requirements but may be used to assist in the deployment of liferafts. If the basic flotation system has demonstrated compliance with the minimum flotation and trim requirements, credit for a sea anchor or similar device to achieve stability in more severe water conditions (sea state, etc.) may be allowed if the device can be automatically, remotely, or easily deployed by the minimum flightcrew.

(v) Probable rotorcraft door/window open or closed configurations and probable damage to the airframe/hull (i.e., failure of doors, windows, skin, etc.) should be considered when demonstrating compliance with the flotation and trim requirements.

(4) Float System Reliability. Reliability should be considered in the basic design to assure approximately equal inflation of the floats to preclude excessive yaw, roll, or pitch in flight or in the water.

(i) Maintenance procedures should not degrade the flotation system (e.g., introducing contaminants which could affect normal operation, etc.).

(ii) The flotation system design should preclude inadvertent damage due to normal personnel traffic flow and excessive wear and tear. Protection covers should be evaluated for function and reliability.

(5) Occupant Egress and Survival. The ability of the occupants to deploy liferafts, egress the rotorcraft, and board the liferafts should be evaluated. For configurations which are considered to have critical occupant egress capabilities due to liferaft locations and/or ditching emergency exit locations and floats proximity, an actual demonstration of egress may be required. When a demonstration is required, it may be conducted on a full-scale rotorcraft actually immersed in a calm body of water or using any other rig/ground test facility shown to be representative. The demonstration should show that floats do not impede a satisfactory evacuation.

(6) Rotorcraft Flight Manual. The Rotorcraft Flight Manual is an important element in the approval cycle of the rotorcraft for ditching. The material related to

ditching may be presented in the form of a supplement or a revision to the basic manual. This material should include:

(i) The information pertinent to the limitations applicable to the ditching approval. If the ditching approval is obtained in a segmented fashion (i.e., one applicant performing the aircraft equipment installation and operations portion and another designing and substantiating the liferaft/lifevest and ditching safety equipment installations and deployment facilities), the RFM limitations should state “Not Approved for Ditching” until all segments are completed. The requirements for a complete ditching approval not yet completed should be identified in the “Limitations” section.

(ii) Procedures and limitations for flotation device inflation.

(iii) Recommended rotorcraft water entry attitude, speed, and wave position.

(iv) Procedures for use of emergency ditching equipment.

(v) Ditching egress and raft entry procedures.

FIGURE AC 29.801-1

SEA STATE CODE

(WORLD METEOROLOGICAL ORGANIZATION)

Sea State Code	Description of Sea	Significant Wave Height Meters	Significant Wave Height Feet	Wind Speed Knots
0	Calm (Glassy)	0	0	0-3
1	Calm (Rippled)	0 to 0.1	0 to 1/3	4-6
2	Smooth (Wavelets)	0.1 to 0.5	1/3 to 1 2/3	7-10
3	Slight	0.5 to 1.25	1 2/3 to 4	11-16
4	Moderate	1.25 to 2.5	4 to 8	17-21
5	Rough	2.5 to 4	8 to 13	22-29
6	Very Rough	4 to 6	13 to 20	28-47
7	High	6 to 9	20 to 30	48-55
8	Very High	9 to 14	30 to 45	56-63
9	Phenomenal	Over 14	Over 45	64-118

NOTES: (1) The Significant Wave Height is defined as the average value of the height (vertical distance between trough and crest) of the largest one-third of the waves present.

(2) Maximum Wave Height is usually taken to be 1.6 x Significant Wave Height; e.g., Significant Wave Height or 6 meters gives Maximum Wave Height of 9.6 meters.

(3) Winds speeds were obtained from Appendix R of the “American Practical Navigator” by Nathaniel Bowditch, LL.D.; Published by the U.S. Naval Oceanographic Office, 1966.

AC 29.803. § 29.803 (Amendment 29-3) EMERGENCY EVACUATION.

a. Explanation. The regulation specifies that "means for rapid evacuation in a crash landing" be provided considering the landing gear extended or retracted, and "considering the possibility of fire." Any external exits, whether normal entrance doors or service doors, can be considered as emergency exits if the requirements of §§ 29.805 through 29.815 are met. "Limited amphibian rotorcraft" emergency exits are required to be designed for probable maximum local water pressure (or shown to have nonhazardous failure characteristics) and to have a specified number of exits above the water level. Limited amphibian rotorcraft are approved under the provisions of §§ 29.519 and 29.755(b). Sections 29.801 and 29.807(d) refer to similar standards that pertain to "rotorcraft ditching configurations."

b. Procedures. Exits, arrangement, markings, access, and aisle widths as specified in § 29.805 through 29.815 are to be provided. Recent rotorcraft designs have been approved under the "ditching" standards of § 29.801. Previous "limited amphibian rotorcraft" were designed to the same standards.

AC 29.803A. § 29.803 (Amendment 29-30) EMERGENCY EVACUATION.

a. Explanation.

(1) Amendment 29-30 removed § 29.803(c) which concerned limited amphibians, now obsolete with adoption of § 29.801 ditching standards, and added § 29.803(d) for evacuation criteria of certain rotorcraft designs. Part 29, Appendix D evacuation procedures was adopted concurrently. In addition, newly adopted § 29.803(e) allows use of analysis and tests for compliance with the standard.

(2) This amendment adds explicit demonstration requirements even for certain smaller but "dense" interior arrangements as stated in § 29.803(d)(2).

(3) The 90-second duration for an evacuation demonstration through all exits on one side of the rotorcraft is a primary addition to the standard.

b. Procedures. All of the policy material pertaining to this section remains in effect with the following additions:

(1) For rotorcraft with a seating capacity of more than 44 passengers, conduct an emergency evacuation in accordance with the provisions of Part 29, Appendix D.

(2) For certain smaller rotorcraft with a van or limousine-type "dense" interior as defined in § 29.803(d)(2), conduct an emergency evacuation in accordance with the provisions of Part 29, Appendix D. The rotorcraft should meet all three requirements before a demonstration is specifically required.

(3) Part 29, Appendix D contains procedures. Safety equipment for alleviating "ground" injuries is contained in paragraph (c) of the Appendix.

(4) A combination of analysis and tests may be used in lieu of test only. A combination of tests and analysis is particularly intended to evaluate emergency evacuations from rotorcraft from 10 to 44 passengers with van or limousine-type interiors. Test other than full-scale evacuation tests may be used in conjunction with analyses to evaluate specific design features such as folding seat backs which affect only one or two passengers. That is, sections of an interior may be used to evaluate a feature and its effects on prompt evacuation of the rotorcraft.

AC 29.805. § 29.805 (Amendment 29-3) FLIGHTCREW EMERGENCY EXITS.

a. Explanation. Flightcrew emergency exits are required when passenger exits are not convenient. The placement of litters, cargo, or bulkheads may prevent passenger exits from being convenient to the flightcrew. Flightcrew exits, if required, are to be of sufficient size and located on both sides of the rotorcraft (or one top hatch) to "allow rapid evacuation of the flightcrew." A test or tests are required.

b. Procedures. Flightcrew emergency exits, if required, may consist of one overhead hatch or two side exits (one on either side). The size is not explicitly defined except that it be "of sufficient size . . . to allow rapid evacuation of the flightcrew." The ability for "rapid evacuation" should be demonstrated by test. For side exits located immediately adjacent to the crew seat and exceeding Type IV exits (§ 29.807) in size, the test demonstration can be accomplished by normal use and evaluation of the exits by the FAA/AUTHORITY crew during Type Inspection Authorization (TIA) testing. For any overhead exit or side of fuselage exits not meeting Type IV dimensions, a special demonstration test should be accomplished. This demonstration should show that 2.5 percentile to 97.5 percentile men could egress rapidly through the crew exit(s), i.e., men 5 feet 5 inches to 6 feet 2 inches in height and up to 210 pounds in weight.

AC 29.805A. § 29.805 (Amendment 29-30) FLIGHTCREW EMERGENCY EXITS.

a. Explanation. Amendment 29-30 adds a new paragraph § 29.805(c) which requires that water or flotation devices not obstruct the flight crew emergency exits after a ditching. Test, demonstration, or analysis is required for substantiation.

b. Procedures.

(1) The tests, demonstrations, or analysis required by § 29.805(c) for flight crew exits is analogous to those of § 29.807(d)(3) except the crew exit threshold may be slightly below the water line but should not obstruct use of the exit.

(2) Tests in water (tanks or large bodies of water) or demonstrations in the laboratory may be used for compliance if the deflections of flotation devices relative to the exits are accurately or conservatively achieved.

(3) Obstructions should be identified, should be minor, and should not interfere with exit removal or opening, or with crew egress.

AC 29.807. § 29.807 (Amendment 29-12) PASSENGER EMERGENCY EXITS.

a. Explanation. The normal passenger exits (type and number in each side of fuselage) are specified as follows:

(1) For overland operations.

Passenger Seating Capacity	Emergency exits (rectangular with corner radii of width/3) for each side of the fuselage			
	Floor level			Step-up -29" Max.
	Type I 24" X 48"	Type II 20" X 44"	Type III 20" X 36"	Type IV 19" X 26"
1 through 10				1
11 through 19			1 or	2
20 through 39		1		1
40 through 59	1			1
60 through 79	1		1 or	2

(2) For overwater operations (related to ditching an optional standard).

Passenger Seating Capacity	Emergency exits (rectangular with corner radii of width/3) for each side of the fuselage	
	Threshold Above Waterline	
	Type III 20" X 36"	Type IV 19" X 26" w/step-up - 29" MAX
1 through 9		1
10 through 35	1*	
Each Additional or Partial Unit of 35	1*	

*The passenger seat-to-exit ratio may be increased by using larger exits if proven by analyses or tests.

(3) For crash rollover conditions. Sufficient top, bottom, or ends of fuselage exits are to be provided for evacuation unless the probability of the rotorcraft coming to rest on its side in a crash landing is extremely remote.

(4) Ramp exits to replace Type I or II exits are permitted.

(5) Each emergency exit must be functionally tested.

b. Procedures.

(1) The number and size of overland and overwater operation exits will be as specified. The use of oversize exits is allowed if the threshold is flat and of the specified width.

(2) The top, bottom, or end fuselage exits should be provided unless features of design are provided which prevent the rotorcraft from coming to rest on its side in a crash landing, and unless sufficient fail-safe and fatigue tests and analyses are conducted of the landing gear and support structure to show it is unlikely that the rotorcraft will come to rest on its side as a result of a single structural failure. An analysis is generally necessary to prove compliance with § 29.807(c).

(3) Ramp exits may be used in place of one Type I or one Type II exit if the required Type I or Type II exit is impractical, and if the § 29.813 exit access requirements are met by the ramp exits.

(4) Each emergency exit is to be opened from the inside and the outside as a functional test. Interior panels and seats should be installed for the exit functional tests to check for interferences and other effects. Section 29.813 pertains to access to the exits.

AC 29.807A. <u>§ 29.807 (Amendment 29-30) EMERGENCY EXITS</u>.

a. <u>Explanation</u>. Amendment 29-30 added § 29.807(d)(3) which requires proof that all ditching configuration exits will be free of interference from emergency flotation devices, whether stowed or deployed (inflated). The threshold for each of these “ditching” exits should be above the water line in calm water.

b. <u>Procedures</u>.

(1) Test, demonstration, compliance inspection, or analysis is required to show freedom from interference from stowed and deployed emergency flotation devices. In the event an analysis is insufficient or a given design is questionable, a demonstration may be required. Such a demonstration would consist of an accurate, full-size replica (or true representation) of the rotorcraft and the flotation devices while stowed and after their deployment.

(2) The type inspection authorization may be used to perform compliance evaluation utilizing a full-scale rotorcraft in calm water. Designs may be accepted “by compliance inspection” if location of exit and flotation devices relative to each other ensures that interference is impossible. In this case, a demonstration is unnecessary.

AC 29.809. § 29.809 (Amendment 29-3) EMERGENCY EXIT ARRANGEMENT.

a. Explanation. Emergency exits are to be provided which result in an unobstructed opening to the outside. The following emergency exit requirements are the same as passenger door requirements of § 29.783 and noted for convenience.

(1) Openable from inside or outside.

(2) Simple and obvious means for opening.

(3) Means for locking.

(4) Means to prevent opening in flight inadvertently or as a result of mechanical failure.

(5) Means to minimize jamming in a minor crash landing.

NOTE: In addition the following emergency exit requirements are: (1) the means of opening may not require exceptional effort; and (2) a slide (for floor level exits) or rope must be provided as prescribed for exits whose thresholds are more than 6 feet from the ground (unless located over the wing). Sections 29.1411(c) and 29.1561 contain other standards for the descent devices.

b. Procedures. Subparagraphs 1 through 5 of the above explanation are covered in the procedure for § 29.783, paragraph AC 29.783.

(1) The effort required to open the exit can be evaluated when the tests of § 29.807(f) are conducted. If the effort required to open the exit is in the range of 40 to 50 pounds, it is recommended that a person of slight stature, such as a female in the 90 to 110 pound weight range, be used for the exit opening demonstration/test. In any case, the average load required to operate the exit release mechanism and open the exit should not exceed 50 pounds, and the maximum individual load of a test series should not exceed 55 pounds.

(2) If an approved escape slide, or its equivalent, is provided for exits more than 6 feet from the ground with the landing gear extended, it should be located near the door and conspicuously marked. Automatic inflation and deployment under emergency conditions are the preferred means of operation but are not required by § 29.809. If automatic inflation and deployment features are provided, design features should prevent inadvertent deployment if the exit is a door used for normal entry and/or service. If manual deployment methods are used, they must be simple and easily carried out by a person of slight build and strength. The slide should rapidly inflate upon deployment. See § 29.809(f) for standards concerning an escape rope.

AC 29.809A. <u>§ 29.809 (Amendment 29-30) EMERGENCY EXIT ARRANGEMENT</u>.

a. <u>Explanation</u>.

(1) Amendment 29-29 added the phrase, "under the ultimate forces in § 29.783(d)," to clarify that the following inertial load factors previously stated in § 29.809 were not altered by Amendment 29-29 and that the previous design conditions still apply to § 29.809(e) exits as well as the doors:

(i) Upward - 1.5g

(ii) Forward - 4.0g

(iii) Sideward - 2.0g

(iv) Downward - 4.0g

(2) Amendment 29-30 further revised the requirements of § 29.809 by:

(i) Amending requirements of § 29.809(f) to include landing gear malfunction or failure in determining the distance from the exit to the ground. (A means is required to assist occupants in descending to the ground when that distance is more than 6 feet);

(ii) Adding specific requirements for automatic slides, automatic slide deployment (not optional), and slide qualification in a new § 29.809(g);

(iii) Allowing relaxation in § 29.809(h) such that a rope or other assist means may be used rather than a slide for rotorcraft having 30 or fewer passenger seats provided an evacuation demonstration is successfully accomplished; and,

(iv) Moving but not changing the egress rope requirements formerly in § 29.809(f) to a new § 29.809(i).

b. <u>Procedures</u>.

(1) The procedures of paragraph AC 29.809 continue to apply except compliance should consider landing gear collapse, breaking, or not extending as well as slide deployment and proper inflation in 25 knot winds.

(2) Automatic deployment of slides is now a requirement, not an option.

(3) Procedures for slide qualification tests are explicitly provided in § 29.809(g)(5).

AC 29.811. <u>§ 29.811 (Amendment 29-24) EMERGENCY EXIT MARKING</u>.

a. <u>Explanation</u>.

(1) This regulation covers both the marking and exit interior illumination by emergency lighting prior to Amendment 29-24.

(2) With adoption of Amendment 29-24, the interior emergency lighting standards were moved to § 29.812, and exterior emergency lighting standards were added. However, the standards for emergency lighting in § 29.812 apply to transport Category A rotorcraft. Transport Category B rotorcraft shall have the "emergency" lighting required in § 29.811(d). General interior lighting standards are no longer specified in § 29.811.

(3) Locating and marking signs are specified for each emergency exit with the following features:

(i) Locating signs and marking signs are to--

(A) Be recognizable from a distance equal to the width of the cabin;

(B) Have 1-inch white letters on a 2-inch red background (colors may be reversed); and

(C) Be self- or electrically illuminated to a minimum brightness of 160 microlamberts.

(ii) Locating signs visible to occupants approaching along the main aisle are required for each exit.

(A) The sign is required next to or above the aisle for floor level exits.

(B) Bulkheads or dividers obscuring exits must have exit locating signs except as stated.

(4) Exit operating or release handle instructions are to be--

(i) Readable from a distance of 30 inches; and

(ii) Supplemented with a red arrow and sign (for Type I or Type II exits with a handle having rotary motion) with the following features provided:

(A) A red arrow with a ¾-inch shaft, a head of twice the shaft width, and a 70° arc at 75 percent of handle length.

(B) The word "open" in red letters 1 inch high near the head of the arrow.

(5) Emergency lighting.

(i) Prior to Amendment 29-24, an independent source of light, as prescribed, shall be installed in transport Category A or B rotorcraft to:

(A) Illuminate marking and locating signs;

(B) Provide general lighting of 0.05 foot-candles at 40-inch intervals at armrest height along the main aisle; and

(C) Operate manually and automatically in a crash landing and when the normal electrical power is interrupted.

(ii) Amendment 29-24 requires for transport Category B rotorcraft either self- or electrically illuminated exit marking and locating signs. General lighting standards are not specified. See § 29.812 for transport Category A standards.

(6) External exit markings are required which include a 2-wide band around the exit, identification, and instructions for opening. The external markings are to have a reflectance difference of 30 percent from the fuselage surface finish.

(7) Emergency exits signs may read simply “EXIT.”

(8) Excess exits should meet all of the “EXIT” standards or should not be identified as an exit.

b. Procedures.

(1) Emergency exit locating signs may be located to the side of the aisle for small fuselage heights, rather than over the aisle where they may present a hazard to the occupant’s head and possibly impede egress. For small passenger cabins one self-illuminated sign stating “EXIT” may be used as both the locating and marking sign for an individual exit on one side of the cabin (operating instructions will, of course, still be required). If one “EXIT” sign is used to both locate and mark the exit, it should be attached to the fuselage above the exit and not to the exit itself. If it is attached to the exit itself and the exit is discarded from the cabin after opening, the locating function of the exit sign is lost when the exit is removed. That is, there is no sign to locate the exit for passengers other than for the one who discarded the exit. The exit locating sign is a necessity to direct all occupants.

(2) Operating instructions should be provided as specified. They should be kept short but clear; e.g., “rotate handle,” “push,” “pull,” etc.

(3) Lighting should be provided as specified to illuminate the cabin for egress paths and to supplement lighting of the exit operating instructions signs.

(4) The reflectance of external exit markings can be checked by appropriate electro-optical instrumentation or by use of photometer card sets. AC 20-47, Exterior Colored Band Around Exits on Transport Airplanes, provides information for complying with identical standards contained in § 25.811. These are also acceptable for § 29.811. The Munsell Color Company, 2441 North Calvert Street, Baltimore, Maryland 21218, provides a set of cards which includes shades of most commonly used colors.

AC 29.811A. § 29.811 (Amendment 29-31) EMERGENCY EXIT MARKING.

a. Explanation.

(1) Amendment 29-30 changes § 29.811(f)(1) to allow marking or outlining the handles, release devices, levers, etc., of passenger emergency exits which are "normally used doors," rather than outline the entire door of smaller transport rotorcraft. If an exit, other than a normally used door, such as a hatch, window, etc., is approved, that exit would be marked around the perimeter as described.

(2) Amendment 29-31 added two requirements to § 29.811(a):

(i) A clarification that emergency exit markings should be conspicuously marked for egress in darkness as well as in daylight.

(ii) A requirement for visibility of emergency exit markings when the "rotorcraft is capsized (in water) and the cabin is submerged. This standard applies to rotorcraft configurations complying with § 29.801.

b. Procedures. The procedures of paragraph AC 29.811 are still applicable plus:

(1) The release device, handle, etc., of the normally used door(s) may be separate from the normally used handle of the door (such as a release system lever for sliding door rollers). To preclude jamming a sliding door, which is also an exit, in an emergency landing impact, the door should be released from the track. An emergency release handle for releasing door rollers may be used to allow the exit door to be "pushed off" the track. For smaller rotorcraft, such a release lever should comply with the necessary operating procedures and exit markings but should use a distinct, separate 2-inch wide band around the release lever per § 29.811(f)(1). That is, a distinct "band" is necessary to comply rather than a solid block of color around the release lever. Large rotorcraft should have exits marked with a distinct 2-inch band around the exit perimeter as stated in subparagraphs § 29.811(f)(1). Refer to paragraph AC 29.811 for color contrast.

(2) The interior compliance checklist should report that emergency exit markings have been evaluated by "interior compliance inspections" conducted in darkness as well as daylight, and visibility of interior emergency exit markings should be checked under submerged cabin conditions or alternate/equivalent means for those

rotorcraft configurations equipped for over-water flights that are approved under § 29.801.

AC 29.812. § 29.812 (Amendment 29-24) EMERGENCY LIGHTING.

a. Explanation. Section 29.812 was added by Amendment 24. This change unified the requirements for an emergency lighting system into a single paragraph and required these systems only for Category A rotorcraft. The purpose of this change was to afford passengers flying in Transport Category A rotorcraft the same level of safety in an emergency evacuation at night as passengers flying in transport category airplanes.

b. Procedures. This paragraph is quite similar to the emergency lighting system required for Part 25 airplanes. The exception is there are no requirements in this paragraph for floor proximity emergency escape path markings. The following items should be considered in the design of emergency lighting systems:

(1) There is a requirement for two controls of the system. One of these controls is located in the cabin, where it can be operated by a flight crew member or a passenger. The other control is located in the cockpit. These switches must have an “ON,” “OFF,” and “ARMED” position. These switches should operate independently of each other, and any other systems in the rotorcraft. The emergency lights must become lighted or remain lighted if the switch is either turned on, or the switch is in the armed position and there is an interruption of the rotorcraft electrical power supply. Inertia switches should not be used to satisfy this requirement.

(2) Sharing of light bulbs with the normal cabin lighting is acceptable provided there is sufficient isolation of the emergency lighting system from the normal cabin lighting circuits. No single failure of the shared portion should render the emergency lighting system inoperative.

(3) The luminosity tests of the emergency lighting system should be accomplished with the emergency exits open.

AC 29.813. § 29.813 (Amendment 29-12) EMERGENCY EXIT ACCESS.

a. Explanation. Paragraph (a) of § 29.813 prescribes design details for passageways, both between passenger compartments and for access to Type I and II emergency exits, should they be provided. Such passageways are not made mandatory by § 29.813 although most larger rotorcraft have used them. Some utility or “wide-body” rotorcraft may have open areas between the crew area (pilots) and passenger area (cabin). These configurations may have lateral seating arrangements providing access to emergency exits of Type I or II size, even though they may not be required by § 29.807(b). These designs may not have a main aisle.

(1) Paragraph (c) of this standard concerns access to Type III and Type IV exits. Although “passageways” with explicit requirements are not required for Type III

and Type IV exits, "access from each aisle to each Type III and Type IV exit" is required.

(2) For exits whose thresholds are more than 6 feet above the ground, additional space adjacent to the exit is required to allow room for a crewmember to assist passengers with the descent device such as an escape slide or rope noted in § 29.809(f).

(3) In addition to requiring passageways and crewmember space adjacent to exits over 6 feet above the ground, this standard does not allow obstructions in the projected opening of Type III or Type IV emergency exits for one seat width from the exit, except as noted. For passenger seating configurations of 19 or less, minor obstructions into the projection of the exit are allowed only if "compensating factors to maintain the effectiveness of the exit" are provided.

b. Procedures.

(1) The provision for unobstructed passageways, at least 20 inches wide as specified, is straightforward for medium or large cabins with a main aisle and a typical rectangular floor plan. Care should be taken to assure that seats (with lateral or fore-and-aft movement) or galleys (with doors or drawers) are not installed so that they can encroach upon the required passageway. Design features such as stops in seat tracks, seat back mechanisms, stops in galley door (or drawer) mechanisms may be required to assure that unobstructed passageways are provided.

(2) The requirement (added by Amendment 29-12) that "access from each aisle to each Type III and Type IV exit" be provided may add design features to the interior of many typical compact interiors of medium-size rotorcraft. Rotorcraft with emergency exits located in either hinged or sliding doors and having passenger area encroachment or protrusions by compartments for fuel cells, gear boxes, etc., may require special design features to assure that passengers seated to one side or one area of the cabin have "access" to all Type III or Type IV exits on the same or other side of the rotorcraft. The cabin must not be separated into compartments or partitioned. For example, fold down seat back mechanisms may be required for compact cabin configurations having only lateral aisles rather than longitudinal aisles and having Type III or Type IV exits located on each side of the cabin at the end of the lateral seat row or rows.

(3) The space adjacent to an exit that requires a crewmember to assist passengers with descent devices must be large enough to prevent the crewmember from becoming an obstruction in access to the exit. Twenty inches of access must be maintained.

(4) Minor obstructions are allowed in the projected opening of Type III or Type IV exits (for 19 or less passenger seat configurations) if "compensating factors to maintain the effectiveness of the exit" are provided. Compensating factors may include

such design features as larger than required exit opening, additional exits beyond the minimum number required, or steps or other assist features which facilitate egress through the exit with the obstruction. Test or analysis may be required to prove the effectiveness of the compensating feature.

AC 29.815. § 29.815 (Amendment 29-12) MAIN AISLE WIDTH.

a. Explanation. Main aisle widths are specified in the following table:

Passenger seating capacity	Minimum main passenger aisle width	
	Less than 25 inches from floor	25 inches and more from floor
	Inches	Inches
10 or less----------------------------------	12*	15
11 through 19----------------------------	12	20
20 or more--------------------------------	15	20

*A narrower width not less than 9 inches may be approved when substantiated by tests found necessary by the Administrator.

b. Procedures.

(1) Provide the specified aisle minimum width where a longitudinal main aisle is provided in the type design.

(2) Historically, certain rotorcraft with short, wide cabins were initially designed without a longitudinal main aisle for military and cargo use, but were later fitted and approved for civil passenger configuration. These craft generally have 19 or less passenger seats and have either (1) outboard facing passenger seats, (2) a limited number of lateral rows with fold down seats/seat backs, or (3) a combination of lateral and longitudinal rows with and without main aisles to facilitate entrance and egress.

AC 29.831. § 29.831 VENTILATION.

a. Explanation.

(1) This rule specifies minimum ventilation requirements for each passenger and crew compartment. The minimum requirement for fresh air in the crew compartment is that amount that will allow the crew to accomplish their duties without undue discomfort or fatigue which shall be at least 10 ft^3/m per crewmember. The passenger and crew compartments are also required to be free from harmful or hazardous concentrations of gases or vapors. Specifically for carbon monoxide, the concentration may not exceed 1 part in 20,000 parts of air during forward flight. Failure conditions must also be considered when applying this rule.

(2) This rule becomes more significant when engine bleed air is used for conditioning of the passenger and crew compartments' air. Certain data are necessary in order to properly analyze the bleed air provided under normal and malfunction conditions. The airframe manufacturer can normally look to the engine manufacturer for a specification of the maximum amount of air that can be extracted and the temperature of the extracted air. The engine manufacturer also normally provides a failure analysis that identifies ways the bleed air can be contaminated and the associated oil flow rates under each failure condition. The oil manufacturers are in a position to provide information regarding breakdown of the oil under different temperature conditions and the impact of that breakdown on the quality of the air being provided to the passenger and crew compartments.

b. Procedures.

(1) The passenger and crew compartments should be initially analyzed to ensure that at least 10 ft^3/m per crewmember of ventilation air is being provided. The emphasis has been placed on forward flight and, "air scoops" have been one way of showing compliance with this rule. Most installations also include blowers; however, they are normally provided primarily for defogging the windshields, and a secondary benefit is some circulation during ground or hover operation. In addition, the flight test crew should be asked to do a qualitative evaluation to ensure the amount of ventilation air actually provided meets the requirement for the crew to be able to accomplish their duties without undue discomfort or fatigue. In addition, the ventilation devices provided should not excessively increase the noise level in the cockpit. Compliance with the first requirement of § 29.831(a) can therefore be shown by an analysis showing the existence of at least 10 ft^3/m per crewmember, and a report from the flight test crew indicating that the amount actually provided is satisfactory.

(2) The passenger and crew compartment should be monitored under normal operating conditions for the presence of carbon monoxide. A carbon monoxide test kit is normally used for this evaluation. Air is monitored around outlets and different combinations of windows closed/open, heat off/on, air-conditioner off/on, etc., are checked to ensure all conditions are evaluated.

(3) When engine bleed air is used to condition the passenger and crew compartments' air, it should be initially substantiated that under normal operation, the amount of air being extracted does not exceed the limit established by the engine manufacturer. To accomplish this, determine the flight condition that will give the maximum bleed air flow through the flow limiter (venturi). The flow calculations should use this maximum flow condition and should also be made using the maximum tolerance diameter of the venturi throat.

(4) The engine bleed air should also be evaluated under malfunction conditions to determine a worst-case air contamination condition. (A typical worst-case malfunction is for an oil seal to fail in the engine that allows the engine oil supply to be introduced into the airflow.) With information regarding the contaminant, flow rate calculations can be made to predict the contamination levels that will be reached in the passenger and crew compartments and also the associated time duration of passenger and crew exposure. The severity of the exposure to the contaminated air is related to the temperature of the oil when it is introduced into the airflow. For example, synthetic base oils manufactured to MIL-L-7808 or MIL-L-23699 begin to break down into toxic components when the temperature exceeds 300° C (572° F). The oil manufacturers have evaluated this problem and should be in a position to provide data regarding the amount and type of toxic components to be expected, and the effect of introducing those components into the passenger and crew compartments. Therefore, from information supplied by the engine manufacturer, the worst-case air contamination condition can be calculated, and this can be compared with results of the oil manufacturers' tests to determine if the concentrations are harmful or hazardous.

AC 29.833. § 29.833 HEATERS.

a. Explanation. This standard provides that each combustion heater must be approved. The standard contains no provisions regarding functioning of the system, environmental considerations, or malfunctions, therefore, the provisions of §§ 29.1301 and 29.1309 should be used to evaluate those aspects of an installation. The provisions of § 29.831, ventilation, should also be considered, as well as § 29.859, concerning combustion heater fire protection.

b. Procedures.

(1) Technical Standard Order, TSO-C20, was issued June 15, 1949, and amended on April 16, 1951, and concerns Combustion Heaters. If a heater chosen for installation has been qualified to the provisions of TSO-C20, it is considered to be approved. If a unit is not qualified to TSO-C20, a qualification program for the heater itself should be established with FAA/AUTHORITY certification engineers participating in the program as early as possible. The program should be based on the provisions of the TSO.

(2) The TSO refers to the SAE Aeronautical Standard, AS 143B, which specifies certain additional devices, design features, air supply considerations, performance tests, safety controls, environmental considerations, and so forth. Consideration of all of the provisions of the aeronautical standard should result in an approved unit; however, it will not necessarily result in a satisfactory installation. For environmental considerations, it should be possible to specify an environmental spectrum more suitable to rotorcraft by referencing the latest version of Document No. RTCA/DO-160, Environmental Conditions and Test Procedures for Airborne Equipment, rather than AS 143B. Other specifications may also be satisfactory.

(3) The installation evaluation should consider functioning of the system based on the provisions of § 29.1301. Section 29.1309(a) is the regulatory basis for consideration of environmental conditions, and the expected environmental conditions resulting from the installation should be compared to those specified in the TSO. If the two are not compatible, additional environmental considerations are appropriate. The provisions of § 29.1309(b) should be used to evaluate the possible malfunctions of the installed system, and this evaluation should be documented in a fault analysis. The provisions of § 29.831 should be considered since certain standards of ventilation air quality under normal and malfunction conditions are specified. Additionally the provisions of § 29.859 should also be considered.

SUBPART D - DESIGN AND CONSTRUCTION

FIRE PROTECTION

AC 29.851. § 29.851 FIRE EXTINGUISHERS.

a. Explanation.

(1) The standard concerns objective performance criteria for both handheld fire extinguishers in the crew and passenger compartments and built-in fire extinguisher systems if the system is required.

(2) Section 29.853(e) and (f) dictate the quantity and general location of the handheld fire extinguishers.

(3) Section 29.855(d) contains standards for cargo/baggage compartments.

(4) Sections 29.1541 and 29.1561 concern durable and conspicuous markings and placards for location and operation or use of the equipment.

(5) The rotorcraft flight manual should contain appropriate information as well.

(6) Advisory Circular 20-42C, Handheld Fire Extinguishers for use in Aircraft, provides an acceptable means of compliance with the standard.

b. Procedures.

(1) Advisory Circular 20-42C provides valuable information to select the type and size of the handheld extinguishers.

(2) The type design data shall contain appropriate information. One location should be used (recommended) for the crew compartment. Several locations may be selected to allow for evaluation and approval of several extinguishers and their locations in the passenger compartment.

(3) During a compliance inspection of a complete interior, the installation of required and optional extinguishers shall be checked for compliance.

(4) Whenever an extinguisher is installed, even though not required by § 29.853(f), it shall also comply with the standards.

AC 29.853. § 29.853 (Amendment 29-23) COMPARTMENT INTERIORS.

a. Explanation.

(1) Interior materials and components, windows, linings, etc., must meet certain flammability standards as set forth in Amendment 29-17. The rule refers to Part 25, Appendix F (Amendment 25-32), for procedures. Flight Standards Service Release No. 453 contained acceptable flammability standards for specified interior materials prior to adoption of Amendment 29-17.

(2) Smoking may be permitted with use of self-contained removable ashtrays as specified in § 29.853(c).

(3) Fire resistant waste containers may be used as specified.

(4) Hand fire extinguishers are required for flight crewmembers and passengers as specified. Section 29.851 and AC 20-42C, Hand Fire Extinguishers for use in Aircraft, dated March 7, 1984, contain standards for the extinguishers. Section 29.1561(b) concerns identification and operating information signs for the safety equipment, and § 29.1411 concerns accessibility of the equipment.

(5) Amendment 29-23 adopted new flammability requirements for passenger seat and seat back cushions. Section 29.853(b) was added to require tests of “fire blocking” features of the cushions including upholstery materials. The rule refers to Part II, Appendix F, FAR Part 25 or an equivalent for the test procedures and test specimen requirements. Appendix F to Part 25, effective November 26, 1984, is the correct reference.

b. Procedures.

(1) With adoption of Amendment 29-17, materials subject to the flammability standards were significantly expanded. Acrylic windows and signs and transparencies were, for example, included. The rules list the materials and components subject to the flammability standards and refer to Appendix F of FAR Part 25 for the test procedures. Specific burn chambers are also required for the tests. See paragraph b(5) below for flame application time and reference to Appendix F.

(2) A placard prohibiting smoking at all times may be used if ashtrays are not provided. If ashtrays are provided, the installation must have an inner fire resistant liner to close off the ashtray cavity or receptacle when the ashtray is removed. An illuminated sign or signs must be used if prescribed. Each crewmember must be able to control illumination of the sign.

(3) Fire resistant waste containers must have self-closing lids, such as a spring-loaded lid. If a removable container is installed in the receptacle, it must meet the same fire resistant standards as the receptacle. The receptacle must not have any

openings outside the galley or an opening into the rotorcraft structure. An opening may allow accumulation of trash and may allow flames and smoke to go throughout the rotorcraft in case of fire.

(4) A fire extinguisher must be adjacent to crew seats and must be readily accessible to the crew (§§ 29.1411 and 29.853(e)). The extinguisher should be accessible to the crewmember while he is seated. Fire extinguishers are also required in the passenger compartment for seven or more passengers. If one passenger is allowed in the left forward crew seat and six passengers are allowed in the passenger compartment, an extinguisher is not required for the passenger compartment. The extinguisher specified in § 29.853(e) should be located, whenever possible, so that it is visible and convenient to the passengers. If the passenger compartment extinguisher or extinguishers (§ 29.853(f)) are not visible to the passengers when seated, locating signs will be required. See § 29.1561(b).

(5) FAR Part 25, Appendix F, Part 1, established in Amendment 25-32 (effective May 1, 1972) contains flammability test procedures that must be used when complying with § 29.853 of Amendment 29-17. Appendix F refers to sections of FAR Part 25 that do not coincide with sections of the FAR Part 29. To preclude confusion the following statements should be used to develop company test procedures that will provide for compliance with § 29.853.

(i) Section 29.853(a)(1) materials are tested (vertically) to procedures in Appendix F, paragraph (d), and the flame must be applied for 60 seconds and then may be removed.

(ii) Section 29.853(a)(2) materials are tested (vertically) to procedures in Appendix F, paragraph (d), and the flame must be applied for 12 seconds and then may be removed.

(iii) Section 29.853(a)(3) and (4) materials are tested (horizontally) to procedures in Appendix F, paragraph (e), and the flame must be applied for 15 seconds and then may be removed.

(iv) Appendix F, paragraph (h) contains criteria for burn length measurement.

(v) Appendix F, paragraph (f) contains a procedure that does not apply to FAR Part 29, certification rules through Amendment 29-19.

(vi) Appendix F, paragraphs (a), (b), and (c) contain appropriate test procedures. It is noted § 29.853(a)(4) materials are equivalent to the materials specified in § 25.853(b-3).

(vii) Electrical wire and cable materials are tested in accordance with FAR 25, Appendix F, paragraph (g). (Refer to §§ 29.1351(d)(3), 29.831, and 29.863, and possibly special conditions for some rotorcraft.)

(6) AC 23-2, Flammability Tests, dated August 20, 1984, pertains to small airplanes and their materials. This AC includes information from Flight Standards Service Release No. 453 and may be useful in preparing a test proposal for flash-resistant, flame-resistant, fire-resistant, and fireproof materials. FAR Part 1 contains a further definition of these four terms.

(7) The "fire blocking layer" features of the seat cushions must be tested as prescribed in Appendix F, Part II, Part 25. Specific test equipment and devices are prescribed. AC No. 25.853-1, Flammability Requirements for Aircraft Seat Cushions, dated September 17, 1986, provides guidance material for demonstrating compliance with the seat cushion flammability standards.

AC 29.855. § 29.855 (Amendment 29-24) CARGO AND BAGGAGE COMPARTMENTS.

a. Explanation. This section contains standards for accessible and inaccessible compartments. The rotorcraft should be able to contain a fire until it is detected and extinguished or until a safe landing and evacuation are accomplished. The cabin may be used as a cargo compartment for rotorcraft used for carriage of cargo only. Protective breathing equipment is required (§ 29.1439) for an appropriate crewmember or crewmembers when a compartment is accessible in flight. The rule does not provide for classification of cargo compartments. Reference is made to § 29.853 for flammability standards of certain materials.

(1) The compartment must be constructed of, or lined with, materials that are at least fire resistant. Accessible and inaccessible compartments must comply.

(2) Inaccessible compartments must be sealed and designed to completely contain a compartment fire or to allow detection as stated in § 29.855(c) and (d).

(3) Inaccessible compartments must have a detector unless the compartment can contain a fire as stated. Accessible compartments must have a detector or be designed to ensure detection by a crewmember while at his station as stated in § 29.855(d). Flight evaluations assure that an inaccessible compartment is sealed and will contain smoke, gases, etc., as stated.

(4) The cabin area may be used for carriage of cargo only as stated in § 29.855(e). Crew emergency exit must be accessible; sources of heat protected, and air flow must be stopped.

(5) Section 29.853 of Amendment 29-17 provides flammability standards for cargo compartment liners, covers, cargo, baggage tiedown equipment, etc., as stated in

that section. This section pertains to compartments used by passengers or crew. Section 29.855(a) requires a fire resistant liner and is the overriding requirement.

b. Procedures. It is intended to provide for adequate protection of the crew and passengers in the event of an in-flight fire. For Category B rotorcraft, one objective as stated in § 29.861 is that the rotorcraft should be protected for at least 5 minutes (after recognition) in the event of a fire. The correct time interval to consider for Category A or B rotorcraft may be derived from the policy stated in paragraph AC 29.861, § 29.861.

(1) An aluminum inner skin, fire resistant liner, or closure of the compartment, whether the compartment is accessible or inaccessible is required by the rule. In the event of a compartment fire, the inner skin or liner will protect the load-carrying structure from direct flame impingement until the fire is detected and appropriate action is taken. Flight Standards Service Release No. 453 provides the standards for fire resistant materials.

(2) Inaccessible compartments, in addition to having the inner skin or liner, must be sealed to prevent entry of air and thereby contain a fire in the compartment. Flight tests are generally necessary to assure the compartment, primarily doors, do not leak in flight. Sensitive pressure measuring equipment (range of 10 inches of H_2O) may be used to prove the compartment is sealed by finding no appreciable change in compartment pressure during ground and flight conditions. The appropriate tests should also be conducted to determine that no accumulation of harmful quantities of smoke, flame , extinguishing agents, or other noxious gases occur in any crew or passenger compartment. For compartments having a volume not in excess of 500 cubic feet, an airflow of not more than 1,500 cubic feet per hour is considered acceptable. For larger compartments lesser airflow may be applicable to assure fires are contained.

(3) Inaccessible compartments may have a detector as prescribed. A smoke detector is preferable in place of a fire detector. The instrument panel will have an illuminated red indicator, such as baggage/cargo, as a warning signal for the flightcrew. Although no specific standards for the detectors are contained in FAR Part 29, the following standards are recommended. The detection system should be designed to provide a visual indication to the flightcrew within one minute after start of a fire or within 5 minutes after smoke initiation appropriate to the detector used (30 seconds is allowed under TSO C 1b, for smoke detector actuation). There should be a means to allow the crew to check in flight the functioning of each fire or smoke detector circuit. For large compartments, the effectiveness of the detection system should be proven and the detection system should be capable of detecting a fire at a temperature significantly below the temperature at which the structural integrity of the rotorcraft would be substantially decreased.

(4) Accessible compartments must have a detector or detectors unless a crewmember can detect a fire while at his station. Flight evaluations are necessary to assure accessible compartments may be isolated from crew and passenger

compartments as stated. The rule envisaged separate compartments for passengers or crew and cargo/baggage.

(5) Insulation blankets, cargo covers, cargo and baggage tie-down equipment, including containers, bins and pallets used in accessible and inaccessible compartments should meet the flammability standards specified in § 29.853 for the same counterparts noted therein.

AC 29.855A. § 29.855 (Amendment 29-30) CARGO AND BAGGAGE COMPARTMENTS.

a. Explanation. Amendment 29-30 relaxes previous requirements by allowing small, accessible cargo and baggage compartments to be lined with passenger compartment materials rather than fire resistant materials. Materials may meet the requirements in § 29.853(a)(1), (a)(2), and (a)(3) for cargo or baggage compartments if:

(1) The presence of a compartment fire would be easily discovered by a crew member while at the crew member's station;

(2) Each part of the compartment is easily accessible in flight; or

(3) The compartment has a volume of 200 cubic feet or less.

b. Procedures. The previous procedures continue to apply to Amendment 29-30 except for allowing the use of passenger compartment materials for accessible compartments.

AC 29.859. § 29.859 (Amendment 29-2) COMBUSTION HEATER FIRE PROTECTION.

a. Explanation. This regulation ensures that onboard combustion heating systems (of all type designs) are safe during normal and survivable emergency operations. Thus as a minimum, each combustion heater design must meet the requirements of § 29.859.

b. Definitions.

(1) Backfire. An improperly timed detonation (or explosion) of a fuel mixture which results in higher than normal temperatures and pressures.

(2) Reverse flame propagation. An event that occurs when the flame from a controlled combustion process (such as a heater) goes in an abnormal path (i.e., either a reverse or different path than the intended path) as a result of a change in internal pressure or internal pressure gradient (e.g., a backfire) from a detonation or a similar event.

(3) Safe distance. A maximum flow length dimension determined from the thermodynamics of a worst-case flow reversal (backfire) and the local heater system geometry.

(4) Heater zone (or region). A geometric zone defined by the heater type, heater size, the location of heater system components, and the maximum safe distance determined under (3) above. The heater system components may affect the heater zone's size if they are closely located to the heat source. For example a heater fuel tank would not be part of the heater zone if it were located far away from the zone boundary; however, if it were adjacent or close to the boundary, it would be included in the heater zone.

(5) Fireproof. Fireproof is defined in § 1.1, "General Definitions."

(6) Severe Fire. The following thermodynamic definitions are based on AC 20-135, "Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards and Criteria" and on the definitions in § 1.1 for fire resistant and fireproof materials. These definitions are provided for analytical purposes. A severe fire, when used with respect to fireproof materials, is one which reaches a steady state temperature of 2,000 ±150° F for at least 15 minutes. A severe fire, when used with respect to fire resistant materials, is one which reaches a steady state temperature of 2,000 ±150° F for at least 5 minutes.

(7) Hazardous accumulation of water or ice. An accumulation of water or ice that causes a device to not perform its intended function in either normal operation or a survivable emergency situation.

c. Procedures. When suitable data is available, the heating system design should be thoroughly reviewed to determine which system components and arrangements must comply with each subsection of § 29.859. The method-of-compliance relative to each subsection of § 29.859 should then be determined. Acceptable, but not the only, methods of compliance are discussed on a section-by-section basis as follows.

(1) For compliance with § 29.859(a), combustion heater designs, their installations and their heater zones must be identified and thoroughly evaluated. The most direct method of compliance for the heater, itself, is to procure units that already have internal design features that meet the relevant requirements of this section; otherwise, design features should be provided and evaluated during certification that meet these same requirements. Several combustion heaters are approved under TSO-C20. TSO-C20 provides the procurement sources and the detailed approval standards for these combustion heaters. Each heater, its installation and its heater zone should be reviewed against the criteria of §§ 29.1181 through 29.1191 and §§ 29.1195 through 29.1203 (reference paragraphs AC 29.1181 through AC 29.1191 and AC 29.1195 through AC 29.1203) to ensure compliance. Next, the fire detector installation drawings and specifications should be reviewed for each heater region. The

review should consider all reasonable hazards and failure modes of the heater and the detection system, itself. If not previously TSO approved, the detectors themselves should be evaluated and approved during the overall system certification effort. Then, the drainage and venting system for each heater installation should be reviewed to ensure that areas of fuel or fuel vapor collection are properly drained or vented. The capacity of each drain or vent should be determined and, unless impracticable, the flow capacity should be a minimum of 3-to-1 over the worst-case leakage anticipated (including the adverse effects of surface tension). Phased inspections to eliminate clogging should be considered. Finally, the drainage and ventilation systems should be reviewed to ensure that discharges do not create external hazards by entering or contacting external ignition sources such as engine inlets and hot exhausts. If an accurate determination cannot be made by a design review, ground and/or flight test work with dyed, inert fluids or vapors should be conducted to accurately display discharge patterns.

(2) For compliance with § 29.859(f), the ventilating air duct design should be reviewed to determine what ducts are routed through heater zones. Once this has been determined, each duct section running through the heater zone should be made fireproof by either using a fireproof shroud around the existing duct or by using fireproof material for the duct wall. A primary purpose of these certification measures is to eliminate any system leakage that would allow carbon monoxide (a poisonous gas) to enter occupied areas, incapacitate the crew or passengers, and cause a crash. Regardless of the method-of-compliance chosen, periodic checks should be performed during certification using carbon monoxide detection equipment to certify the leak-free integrity of the system. Several such checks should be done during flight test, especially after rigorous maneuvers, to ensure no leakage. It is also recommended that periodic checks using a carbon monoxide detector be conducted in conjunction with phased visual inspections (typically at a less frequent interval than each visual inspection) to ensure continued airworthiness. Carbon monoxide tests are reliable and quickly accomplished without any system disassembly. Continued airworthiness considerations are very important since carbon monoxide is a colorless, odorless, tasteless, poisonous gas that incapacitates an occupant without warning. Carbon monoxide's ability to incapacitate increases with altitude, and has long been suspected as a probable cause for many aircraft accidents. It is the subject of General Aviation Airworthiness Alert No. 137, dated December 1983.

(3) For compliance with § 29.859(c), any design using combustion air ducts should be reviewed to ensure that the ducts are either made from fireproof material or shrouded with a fireproof shroud over a safe distance (see definition). The safe distance should be determined analytically, by test, or a combination, if the analytical results are not conclusive. The design should be reviewed to ensure that combustion air ducts are not connected to the ventilating airstream, except when an informal equivalent safety finding can be made that shows backfires or reverse burning cannot induce flames or fumes into the ventilating airstream under any failure condition or malfunction of the heater or its associated components. Such a finding should require analysis, testing, or a combination for a proper determination. A hazard FMEA should

be conducted to ensure that no flames or fumes can be induced under any failure mode.

(4) For compliance with § 29.859(d), the design and installation of all standard heater control components, control tubing and safety controls should be reviewed to determine the probable points of water or ice accumulation (e.g., sumps, rough surfaces, joints, etc.). If a design review cannot accurately determine these accumulation points, then bench tests and flight tests should be conducted for proper determination. Once these points are identified, the ability of the effected part (or parts) to perform its intended function when water or ice has fully accumulated must be determined for both normal and survivable emergency operations. If the part (or parts) either has not lost its ability to function; has lost part of its ability to function; or has lost all of its ability to function; and the entire system's function is not impaired, then nothing further should be required. However, if the overall system's function is hazardously impaired or lost, as a result of water or ice accumulation on a part (or parts), then rectifying design improvements should be made prior to final approval. These improvements should either alter the part's environment (e.g., relocation, enclosure, insulation, etc.) or eliminate the hazardous accumulation of water or ice (e.g., provide drainage, better sealing, better location, different surface finish, etc.).

(5) For compliance with § 29.859(e), combustion heaters, if used, must have separate, independent safety controls from their standard controls (e.g., air temperature, air flow, fuel flow, etc.) which are remotely located in case of a heater fire, are operable by the crew and automatically shut off the ignition and fuel supply when a hazardous condition exists, (as defined by § 29.859(g)). These separate safety controls must comply with § 29.859(g)(1), must keep the heater off until restarted by the crew or ground maintenance, and must warn the crew when an essential heater is automatically shut down. The safety control system design should be thoroughly reviewed and tested to ensure that it complies and that no hazardous failure modes exist. An FMEA should be conducted to ensure proper compliance.

(6) For compliance with § 29.859(f), each combustion and ventilating air intake's location should be identified, reviewed, and tested to ensure that no flammable fluids or vapors can enter the heater system, ignite and create a fire. If a combustion or ventilating air intake's location is critical or questionable, it should be relocated, shielded, drained, or other equivalent means provided to eliminate the potential fire hazard. If engineering analysis and evaluation are not adequate to make an acceptable safety finding, testing using dyed, inert, leaked fluids or vapors should be conducted.

(7) For compliance with § 29.859(g), each heater exhaust system design should be reviewed, tested, or a combination to ensure proper compliance with § 29.1121 and § 29.1123 (reference paragraphs AC 29.1121 and AC 29.1123, respectively). Each exhaust shroud should be sealed to ensure that leaked flammable fluids or vapors do not contact the hot exhaust and cause a fire. The seal design should be reviewed to ensure that the sealing material is fireproof, is chemically compatible with the relevant fuels and vapors, is durable and is functionally adequate.

If the design review is not conclusive for compliance purposes, then the seal system should be bench tested under pressure while undergoing critical service loads and motions to ensure no leakage occurs. Phased seal inspections should be considered to ensure continued airworthiness. An analysis should be conducted to determine the structural effects on the exhaust system of the worse case restricted backfire (typically a shock wave analysis can be used to determine the peak internal pressure and the resultant load on the exhaust system.) If structural failure would occur, based on the analysis, either the backfire restriction should be reduced or the exhaust design should be structurally improved to eliminate the failure.

(8) For compliance with § 29.859(h), each heater's fuel system design must be reviewed to ensure compliance with the powerplant fuel system requirements of Part 29 that are necessary for safe operation to be achieved. An equivalent safety finding should be made if an application is received that requests partial compliance or non-compliance with the powerplant fuel system requirements of Part 29. The finding should ensure that the safety intent of § 29.859(j) is achieved. Analysis, engineering evaluation, testing, or a combination should be used to substantiate the heater fuel system design. Heater fuel system components that, by leakage or other failures, can induce flammable fluids or vapors into the ventilating air stream should be shrouded by drainable, fireproof shrouds.

(9) For compliance with § 29.859(i), the drain system design should be reviewed to identify parts that may be subjected to high temperature and parts that may be subjected to hazardous ice accumulation in service. The high temperature parts should be evaluated using the methods of compliance for heater exhausts (reference paragraph c(7), above and paragraph AC 29.1123). Drains that would be stopped up from ice accumulation should be protected by relocation, size, shields, heating, or a combination to ensure hazardous fluids and vapors are properly drained away.

AC 29.861. § 29.861 FIRE PROTECTION OF STRUCTURE, CONTROLS, AND OTHER PARTS.

a. Explanation.

(1) As stated in the rule, a Category B rotorcraft must be controllable until landed and a Category A rotorcraft must be controllable and continue its flight after a powerplant fire. For Category B rotorcraft designs with Category A powerplant isolation or Category A rotorcraft, a powerplant fire in one engine compartment must not adversely affect the remaining engine or engines. (Refer to § 29.903(b)). A policy statement on powerplant fire protection provisions was contained in the following note that appeared after Civil Air Regulation (CAR), Part 7, § 7.480, Designated Fire Zones.

> NOTE: For Category B rotorcraft, the powerplant fire protection provisions are intended to ensure that the main and auxiliary rotors and controls remain operable, that the essential rotorcraft structure remains intact, and that the

passengers and crew are otherwise protected for a period of at least 5 minutes after the start of an engine fire to permit a controlled autorotative landing.

(2) To achieve the objectives of the rule, each part of the rotorcraft, as stated in the rule, must be isolated from a powerplant fire by a firewall (§ 29.1191), or for

(i) Category A, must be fireproof and must also comply with § 29.903(b).

(ii) Category B, must be protected so that they can perform their essential functions for at least 5 minutes under any foreseeable powerplant fire condition.

Review Case No. 26 pertains to CAR, Part 6, §§ 6.384 and 6.483. These rules were replaced by §§ 27.861 and 27.1191 respectively. Even though these rules pertain to normal category rotorcraft requirements, the objective statements contained in the review case pertain to the interpretation of the time interval specified by CAR, Part 7, § 7.384(b) and the note under CAR, Part 7, § 7.480 for Category B rotorcraft. These rules have been replaced by § 29.861(b) and § 29.1191, respectively. In the review case, the FAA stated, in part, that the firewall must be fireproof, support appropriate flight and landing condition loads, and prevent flame penetration when subjected to a flame of 2000° F for 15 minutes. Essential structure and controls must be protected for the duration of time appropriate to the rotorcraft operation and be able to carry loads and resist any failure that could cause hazardous loss of control when subjected to the temperature resulting from any foreseeable powerplant fire. Insufficient protection to provide enough time for a controlled landing would represent an unsafe feature or characteristic for the rotorcraft design.

(3) In addition, paragraph AC 29.1193 (§ 29.1193(c)) pertains to allowable opening in engine cowls and to fireproof skins in specified cases.

b. <u>Procedures</u>.

(1) If each part described in the rule is isolated completely by firewalls, compliance is obtained for Category A or B.

(2) If each part described by the rule is made of fireproof material such as steel, compliance is obtained for Category A or B.

(3) For some Category A rotorcraft, § 29.903(b) also imposes additional considerations where structure, controls, and other parts are common to the engine installation. For example, an interconnected engine mount must be fireproof and also perform its function and not affect the remaining engine in case of a powerplant fire. An evaluation should involve propulsion and airframe disciplines.

(4) For Category B certification, if each part described by the rule does not comply as stated in (1) or (2), it must be proven that it will perform its function under the

prescribed conditions. Compliance for Category B may be demonstrated by the following criteria:

(i) The parts must have a positive margin of safety for the appropriate flight and landing condition, including appropriate engine power conditions, under any foreseeable powerplant fire condition. The time interval under consideration here is the time necessary to complete an emergency descent (as described in the flight manual) and landing from the maximum operating altitude for which certification is requested. In no case is the total time interval to be less than 5 minutes.

(ii) The factors affecting the time interval should include the maximum height above the terrain, the maximum operating altitude, the flight manual recommendations for rate of descent, and a reasonable time for recognizing a powerplant fire.

(iii) The factors affecting the change in physical characteristics (strength primarily) of the parts are the temperature of the part, time interval at the elevated temperature, size, heat absorption or rejection.

(iv) The factors affecting the temperature of the part are location and distance from fire and flames, and temperature of the flames (2,000° F ±50° F should be used unless proven otherwise).

(v) The rule requires substantiations for any foreseeable powerplant fire condition. Each rotorcraft design is unique and an evaluation of each design is necessary to establish the fire and flight conditions under consideration.

(vi) A very brief and simple example of compliance noted here may be helpful. This example pertains to a single engine Category B rotorcraft with the engine mounted on top at the fuselage center line. The engine is supported by all steel tubular mounts. The fuselage panel serves as a work deck as well as a firewall. A 15-minute duration is appropriate for this design. A representative panel of the firewall (deck) skin may be subjected to the autorotation flight loads and the landing load. A flame from an appropriate size burner, measuring 2,000° ±50° F at the skin surface, should impinge on the loaded panel for 15 minutes. The panel may deform but must remain intact and sustain the appropriate load. The flame must not penetrate the panel skin.

(vii) Other rotorcraft designs may have engines located on top of the fuselage and under the main rotor. If cowls or firewalls do not isolate the rotors and essential controls, it must be determined by a rational analysis or by temperature measurement that the rotor and essential controls will perform their functions. Air flow through the rotor and factors noted in paragraphs b(4)(ii), (iii), and (iv) are important to an analysis. Compliance with § 29.1193(e)(3), fireproof skins will involve airframe and propulsion disciplines for rotorcraft designs that do not have cowls.

AC 29.861A. <u>§ 29.861 (Amendment 29-30) FIRE PROTECTION OF STRUCTURE, CONTROLS, AND OTHER PARTS</u>.

a. <u>Explanation</u>.

(1) Amendment 29-30 revised the standard for Category B rotorcraft to allow use of parts made from standard fireproof materials of known acceptable dimensions in areas affected by powerplant fires without further proof of qualification. Previously the standard imposed a performance criterion for Category B applications regardless of the materials and part dimensions used.

(2) Fireproof and fire resistant are defined in FAR Part 1, § 1.1.

b. <u>Procedures</u>.

(1) A part with acceptable geometry that is made of steel, or another fireproof material, may be used to comply with the standard.

(2) A material system, panel, or assembly would be equivalent to steel provided it successfully completes the flammability tests described in paragraph AC 29.861b4(vi) for the appropriate time period that includes fire recognition.

AC 29.863 <u>§ 29.863 (Amendment 29-17) FLAMMABLE FLUID FIRE PROTECTION</u>.

a. <u>Background.</u>

(1) The development of current § 29.863 can be traced through CAR 7.483, § 29.863 (1968), NPRM 68-18 (1968), and NPRM 75-26 (Airworthiness Review Notice November 7, 1975) and subsequent Amendment 29-17.

(2) Investigation of two accidents disclosed evidence of in-flight fires caused by leakage of flammable fluids to ignition sources. The revisions to § 29.863 adopted by Amendment 29-17 require significantly more attention to overall fire protection and prevention.

b. <u>Explanation</u>.

(1) Prior to Amendment 29-17, this rule only required either a means to prevent ignition of flammable fluids or vapors or a means to control any resulting fire. Isolation of flammable fluids and vapors from ignition sources by shrouding or sealing was the normal method of compliance. The revised rule further requires the assumption that these means fail or are ineffective and a fire does actually occur. Means to minimize the consequence of these fires should be provided. Specifically identified considerations should include the flammability of any combustible or absorbing materials, electrical faults, malfunction of protective devices, etc.

(2) The rule does not go so far as to require the entire rotorcraft to be a "designated fire zone." Zonal analysis of areas containing flammable fluids may be used to show compliance with the requirements of this section. The general philosophy to be adopted for demonstrating compliance with § 29.863 is illustrated in AC 29.863-1.

c. Methods of Compliance.

(1) To **minimize the probability of ignition** of fluids and vapors after single failure of a component or systems, the following methods may be used. In considering compliance, the actual extent of protective measures required may be related to the situation considering the quantity and flammability characteristics of the fluid, the fire damage tolerance of the area, and the means available to the crew to minimize hazards from a fire.

(i) Shroud and drain flammable fluid systems (including steel fluid lines), fittings, etc. and/or provide fuel and vapor seals with respect to ignition sources (electrical wiring and equipment, hot bleed air lines, etc.). Drains should be designed and positioned to enable systems to be drained until any remaining flammable fluid residue is negligible. The arrangement of drains should be such that the discharge of flammable fluid from the outlet would not constitute a fire hazard, nor could flammable fluid or vapor enter personnel compartments or other portions of the rotorcraft where a hazard of ignition may exist. If flammable fluid drains are routed through personnel compartments, means for protection from damage should be provided to prevent possible entry of flammable fluids or vapors into these compartments.

(ii) Provide other effective separation, ventilation, or overheat shutdown devices, etc., to preclude ignition. Systems using flammable fluids should be separated from potential sources of ignition, including equipment or parts with hot surface temperatures above the ignition temperature of the fluid, such that the risk of fires as a result of leakage or bursting of the fluid system is minimized.

(iii) Ensure that potential ignition sources, such as bleed air lines and electrical equipment in the areas subject to flammable fluids and vapors is either hermetically sealed, shrouded, insulated or ventilated as necessary to minimize the possibility of ignition, or has been tested and shown to be free of ignition capability. An acceptable standard for such laboratory testing is described in AC 29.1309b(1)(iv).

(iv) Place a restricting orifice in fluid pressure lines routed to instruments and transducers.

(v) Ensure flammable fluid carrying lines and drain lines are not located so as to be subject to abrasion during normal operations. Cargo compartments should be evaluated for potential line damage due to cargo movement.

(2) To minimize the hazards if ignition occurs:

(i) Provide fireproof designs, fire wall isolation, or equivalent means for critical structure, equipment and personnel areas, e.g.:

(A) Flammable fluid lines and reservoirs of flammable fluids should be adequately protected against the anticipated type and duration of fire should ignition occur. Drain lines and their fittings, the failure of which would not result in, or add to, a fire hazard need not be Fire-resistant.

(B) Where there is a risk of leaking flammable fluids re-entering the rotorcraft through joints in the cowling or other rotorcraft surfaces to areas where a hazard of ignition may exist, the ventilation of such compartments should, where practical, be arranged to provide an air pressure within the compartment higher than that of the pressure of the ambient air.

(C) Absorbent materials in areas where leakage or spillage of flammable fluids (i.e., liquids, vapors, gases) could occur as a result of normal operation, failures of the equipment, or leakage from joints or unions should be covered or treated to prevent the absorption of hazardous quantities of fluid. Whenever insulation made of absorbent materials is used on pipes, tanks or equipment containing Flammable fluids, suitable precautions should be taken to prevent the wetting of the insulation by Flammable fluids.

(D) All electrical equipment including cables and their accessories should, as far as is practicable, be constructed of material which do not support combustion and which meet the relevant requirements of FAR/JAR25 Appendix F Part 1. Other materials should be applied and/or protected so that the risk arising from a fire is not increased by their use.

(E) It should be shown by analysis and/or tests that there are adequate means to prevent hazardous quantities of smoke, flame, extinguishing agents or other noxious gases produced as a result of a fire from entering any crew or passenger compartment.

(F) All components of the overheat or fire detector system (if applicable) should be at least Fire resistant.

(G) If located in an area where flammable fluids are present, critical structural components, controls, and essential indicating systems required for safe flight must be able to withstand the conditions resulting from a flammable fluid fire in the area so that a safe landing may be made. Under these conditions the structural members and the control devices should be able to carry the loads appropriate to the expected maneuvers including any vibrations normally experienced in flight. The quantity of flammable fluid likely to be present assuming all fluid drains function correctly and the maximum temperature characteristics of the particular flammable fluid may be taken into account in the analysis of the effect of a fire on critical structure. When making the determination that these components can withstand the flammable fluid fire conditions, the time required to detect such a fire should be taken into account.

(ii) In considering compliance, the actual protective measures required may be related to the situation considering the quantity and flammability characteristics of the fluid, the fire damage tolerance of the area, and the means available to the crew to minimize hazards from the fire. Provisions for fire detection, extinguishment, shutoff valves, fire suppression systems, etc., may be considered as alternate means to limit the duration of a fire in lieu of the protective measures listed in (2)(i) above. However, the consequences of spurious or erroneous operation of these systems should also be considered when evaluating the requirement for their provision. If action by the crew is necessary, quick-acting means (not necessarily fire detectors) should be provided to alert the crew in the event of a fire. Details of any action required by the crew must be in the Rotorcraft Flight Manual in accordance with § 29.1585(a).

(3) Compliance with § 29.863(d) requires as a minimum, type design data defining each area where flammable fluids or vapors might escape.

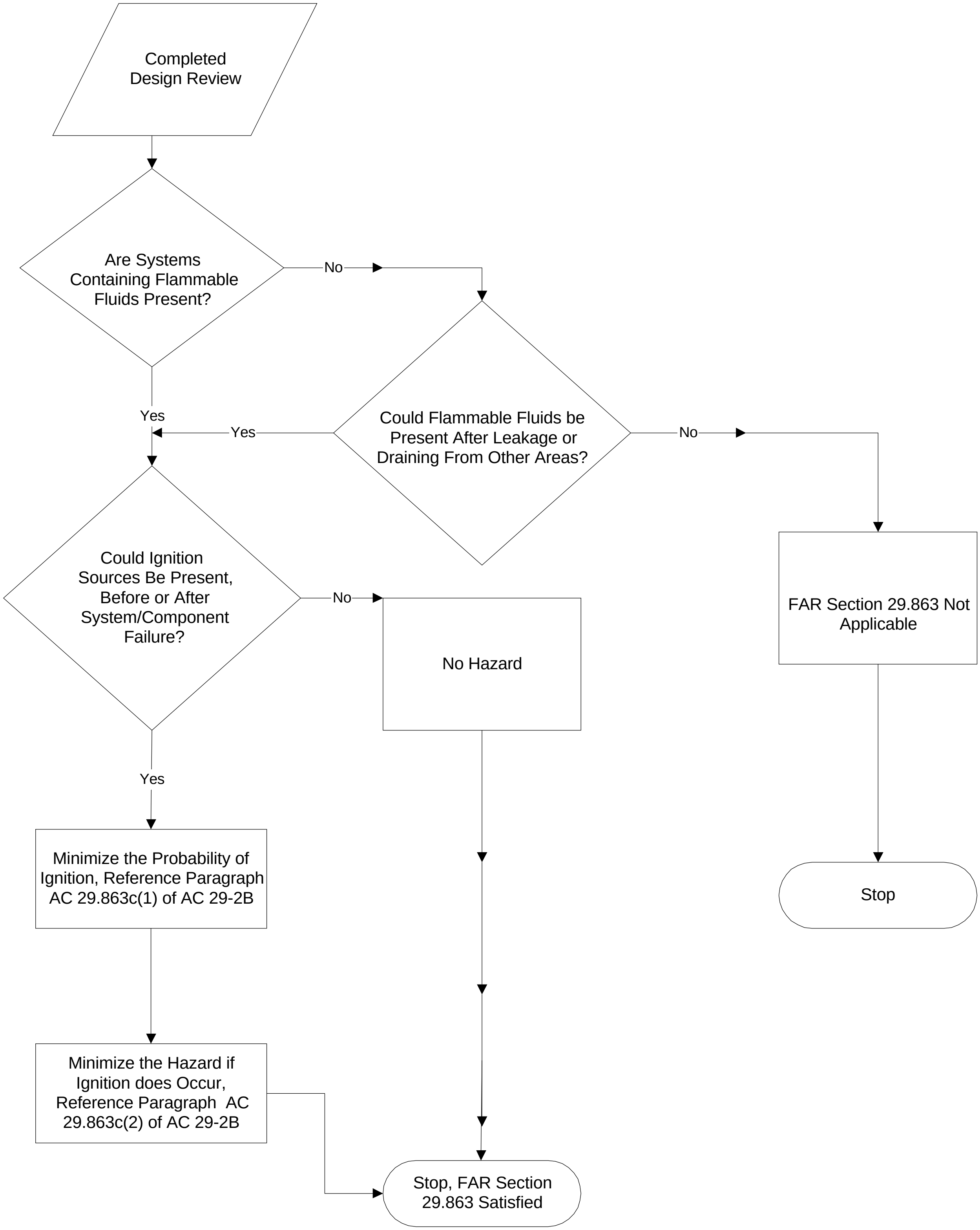

FIGURE AC 29.863-1

SUBPART D - DESIGN AND CONSTRUCTION

EXTERNAL LOAD ATTACHING MEANS.

AC 29.865. § 29.865 (Amendment 29-12) EXTERNAL LOAD ATTACHING MEANS.

a. Background. The external load attaching means standards for transport and normal category rotorcraft were originally contained in Subpart D, “Airworthiness Requirements of FAR Part 133, Rotorcraft External-Load Operations.” Amendment 29-12, in 1977, added a new § 29.865, which moved these standards from Part 133 to Part 29. An identical transfer occurred in 1977 for Part 27. Transport Category A and B rotorcraft were initially used under Part 133 operations and, after Amendment 133-6, restricted category rotorcraft were also included under Part 133 operations. The use of restricted category first came about when an operator, exempt from Part 133, transferred harbor pilots to and from ships by a hoist and sling. The exemption was granted to study the feasibility of passenger transfer outside of the cabin. Subsequently, Amendment 133-9, adopted in January 1987, established a new Class D rotorcraft load combination for transporting passengers external to the rotorcraft. Amendment 133-9 also provided for the limitations and conditions for external passenger transportation and the necessary, associated safety requirements. Part 29 rules have not yet been changed to reflect the Class D requirements.

b. Explanation. While the regulation only addresses external load attaching means, this advisory material also includes guidance for certification of external load carrying devices for rotorcraft to be used in conjunction with Part 133, “Rotorcraft External Load Operations.” Subpart D of Part 133 contains supplemental airworthiness requirements. Part 1 defines four classes of rotorcraft load combinations which are operationally approvable under the Part 133 operating rules and, thus, are eligible for certification under § 29.865. Parts 1 and 133 (through Amendment 133-9) contain a new rotorcraft load combination, Class D, that addresses personnel carried externally. The four classes of rotorcraft load combinations are summarized in figure AC 29.965-1 and are discussed in detail in paragraph c. For further information, AC 133-1A, “Rotorcraft External-Load Operations in Accordance with FAR Part 133,” October 16, 1979, may be reviewed. Also, paragraph AC 29.25 (reference § 29.25) concerns, in part, jettisonable external cargo.

c. Procedures.

(1) The applicant should clearly identify the Parts 1 and 133 rotorcraft load combination classes (A, B, C, or D) that are being applied for. The loads and operating envelopes for each class should be determined and used to formulate the flight manual supplement and basic loads report. The applicant should show by analysis, test, or both, that the rotorcraft structure, the external load attachment means, and (for Class D operations) the personnel carrying device meets the requirements of §§ 29.865(a), 133.41, 133.43, and 133.45(e)(3) for the proposed operating envelope.

(2) For rotorcraft load combination classes A, B, and C, § 29.865 requires use of 2.5 g vertical limit load factor (N_{ZW}) at the maximum substantiable cargo load (which is typical for cargo hauling configurations). This 2.5 g limit load factor is based on an engineering evaluation and a rationalization of § 29.337 for high gross weight applications. However, for lower gross weight configurations (which are more typical of a Class D application; i.e., personnel transport or evacuation), a higher limit load factor is recommended to ensure that limit load is never exceeded in service. For example, a Class D external load carrying device which is certified to a limit vertical load factor of 2.5 g and is installed in a minimum gross weight configuration rotorcraft capable of generating a vertical limit load factor of 3.2 g's could experience ((3.2/2.5 X 1.5) X 100) - 85 percent of ultimate load under emergency conditions with new external hardware. However, if factors such as wear and corrosion have effected the structural integrity of the external hardware ultimate load could be exceeded in emergency service. In any case, FAA/AUTHORITY policy is to not exceed limit load in service. The higher load factor for Class D cases should be the analytically derived maximum vertical limit load factor for the restricted operating envelope being applied for; or, as a conservative option, a vertical limit load factor of 3.5 g's (reference § 29.337). Unless a more rational proposal is received, for Class D cases where maximum operating gross weight for external load is between design maximum weight and design minimum weight, linear interpolation can be used between $N_{ZW\ MIN}$ and $N_{ZW\ MAX}$ versus gross weight for design limit load factor determination.

(3) For applications that employ winches (or hoists) to raise or lower an external load from a hover (or another phase of flight), limit load must be properly determined based on the characteristics of the winch system and its installation such as mechanical advantage, static strength of the winch, static strength of its installation and the payload for any operating scenario being applied for. One acceptable method of determining limit load is by the following procedure:

(i) Determine the basic loads that fail and unspool the winch or its installation, respectively (Note: This determination should be based primarily on static strength; however, any dynamic load magnification factors that are significant should be accounted for).

(ii) Select the lower of the two values from (i) as the ultimate load of the winch system installation.

(iii) Divide the selected ultimate load by 1.5 to determine the limit load of the system.

(iv) Compare the system's derived limit load to the applied for one "g" payload multiplied by the maximum downward vertical load factor ($N_{ZW\ MAX}$) from paragraph (2) to determine the critical payload's limit value.

(v) If the critical limit payload is equal to or less than the system's derived limit load the installation is structurally approvable as presented.

(vi) If the critical limit payload exceeds the system's derived limit load then one of the following options should be considered:

(A) Disapproval.

(B) Application for exemption.

(C) Reduction of the applied for critical limit payload to less than or equal to the system's derived limit load.

(D) Redesign of the winch system (and installation) to increase its derived limit load to equal to or greater than the critical payload.

(E) A combination of options (C) and (D).

(F) Approvable operating restrictions to reduce $N_{ZW\ MAX}$ and, the corresponding critical limit payload to less than or equal to the system's derived limit load.

(4) In all approved cases, appropriate winch system placards and flight manual restrictions should be provided. Also, for Class D load combinations, the winch or hoist should have a demonstrated, acceptable level of reliability (for the phases of flight in which it is operable and in which the Class D load is carried externally). The winch should be disabled (or utilize an overriding mechanical safety device such as a flagged removable shear pin) to prevent inadvertent load unspooling or release during the phases of flight that the load is carried externally and operation is not intended. The maximum allowable winch cable angle should be determined and approved. This is primarily a structural requirement but should also be reviewed from an interference and flight handling criteria standpoint.

(5) It is recommended that winch or hoist systems be demonstrated as follows:

(i) At least 1/3 of the demonstration cycles should include the maximum aft angular displacement of the load from the drum applied for under § 29.865(a).

(ii) The load versus speed combinations of the winch should be demonstrated by showing repeatability of the no load-speed combination, the 50 percent load-speed combination, the 75 percent load-speed combination and the system limit load-speed combination.

(iii) A minimum of six consecutive, complete operation cycles should be conducted at the system's critical limit load speed combination.

(iv) In addition, the demonstration should cover all normal and emergency modes of intended operation and should include operation of all control devices, limit switches braking devices, and overload sensors in the system.

(v) Quick disconnect devices, and cable cutters should be demonstrated at 25 percent, 50 percent, 75 percent, and 100 percent of system limit load. Any electrical load release devices for Class D loads should be treated as a novel design feature and should be coordinated with the Rotorcraft Directorate.

(vi) Any devices or methods used to increase the mechanical advantage of the winch should also be demonstrated.

(vii) During each demonstration cycle, the winch should be operated from each station from which it can be controlled.

(viii) Operating manuals, flight manuals, and associated placards should be used and proofed during the demonstration.

(6) For all applications, it is good practice to obtain the gross weight range limits, the corresponding limit load factors (N_{ZW}), and substantiate the system, accordingly, for the critical loads. This procedure determines the critical basic loads and associated operating envelope for the rotorcraft load combination categories requested.

(7) For a request involving more than one class of rotorcraft load combinations, structural substantiation is required only for the critical case if accurately determinable from analysis.

(8) Appropriate placards, markings, and flight manual restrictions should be provided as determined by load capacities and operational restrictions. Each placard, marking, and flight manual supplement should be checked during TIA flight testing.

(9) For load Classes A, B, C, and D, the basic vertical limit load factor (N_{ZW}) from (c)(2) is converted to ultimate by multiplying the maximum applied load (i.e., the sum of the carrying device load and cargo or personnel loads) by 1.5 (for restricted category approvals, see guidance in paragraph AC 29 MG 5.) This load is used to substantiate all existing structure affected and all added structure associated with the external load carrying device and its attachments. Casting and/or fitting factors are to be applied where appropriate. For load Class D, the weight of each occupant carried externally should be assumed, for analysis purposes, to be that of the 95 percentile (202 pound) man (reference MIL-STD-1472, “Human Engineering Design Criteria for Military Systems, Equipment and Facilities).

(10) For load Classes B, C, and D, the maximum limit external load for which certification is requested, even though it may otherwise be much less than the maximum system capacity; e.g., cargo hook capacity, etc., should not exceed the rated

capacity of the quick release device used in the applicant's proposed design or, for Class D only, the rated capacity of the personnel carrying device. The quick release and personnel carrying devices should be strength tested (with FAA/AUTHORITY witness) or otherwise structurally substantiated to determine their allowable limit load capacity, if it has not been previously approved or was not produced to a recognized and approvable industry or military standard.

(11) For load Classes B, C, and D, in substantiating analyses and tests, the maximum ultimate external load is specified to be applied at the sling-load-line to rotorcraft vertical axis (Z axis) angles up to 30°, except for the forward direction. The 30° angle may be reduced, if impossible to obtain due to physical constraints, or operating limitations. If the angle is reduced, appropriate placards and flight manual changes are required.

(12) For load Classes B and C, an external releasing system is mandated which requires an approved primary quick release device to be installed on one of the pilot's primary controls. The quick release device (typically installed on the cyclic stick) is designed and located to allow the pilot to accomplish load release without hazardously limiting his ability to control the rotorcraft during emergency situations. A manual (backup) mechanical quick release device is also required. This control must also be readily accessible to the pilot or another designated crew member, such as a hoist operator. For Class B and C cargo applications, a sufficient amount of slack should be provided in the control cable to permit cargo hook movement without tripping the hook release.

(13) For Load Class D, an emergency release system is specified by § 133.45(e)(4) which requires two distinct actions for load release. This is intended for the phases of flight that the load is carried (and/or retrieved) externally. This release can be operated by the pilot from a primary control or, after a command is given by the pilot, by a dedicated crewmember from a remote location. Two distinct actions are required for the primary release to provide a higher level of safety for Class D human external loads. If the manual backup device is a cable cutter, it should be properly secured but readily accessible to the dedicated crewmember intended to use them.

(14) For Class D (human) load applications, to ensure personnel safety, the emergency release system design and associated placarding should be given special consideration. As stated previously, electrical release designs should be reviewed by the Rotorcraft Directorate prior to approval.

(15) For the majority of Class D applications, an approved single or multiple personnel carrier or container is required. The carrier or container may be previously approved or may be approved as part of the certification process. In any case, the single or multiple personnel carrier or container should be substantiated for the allowable ultimate load as determined under paragraphs c(2), (3), (4), (5), (6), (7), (8), and (9) above. The personnel carrier or container should be placarded for this capacity and show the proper internal arrangement and/or location of the intended occupants.

Some exceptions may exist that are certifiable under Class D that involve the technique of “Rappelling” from a rotorcraft. Rotorcraft load-combination D allows for such applications by definition (reference § 1.1). Other types of human cargo devices can be applied for under the Class D external load combination definition. An example is external carriage of personnel in a conveyance rigidly attached to the rotorcraft (e.g., cage, pod, secured litter or strap harness/seat arrangement).

(16) The personnel carrier or container should be easily and readily ingressed or egressed. Appropriate placards are required to provide ingress and egress instructions. For door latch fail-safety, more than two fastener or closure devices are recommended. Direct visual inspectability of the latch device by both crew and passengers is recommended to ensure it is fastened and secured. Any fabric, if used, should be durable and should meet the flammability standards of safety belts as stated in TSO C-22. Sharp corners and edges should be avoided, and padding should be used when necessary to protect the carrier and container occupants.

(17) The U.S. Coast Guard has three containers or devices that are used with rotorcraft for emergency rescue work. These devices and their National Stock Numbers are listed below. These devices have not been FAA/AUTHORITY approved; however, applications which involve them may be submitted for approval.

National Stock No.	Title
6530-00-042-6131	Stokes litter (one person)
1670-00-HR0-7970	Rescue basket
1680-090-511-2712	Rescue sling (one person)

NOTE: The rescue sling is a “collar” device that requires a person to exert some effort to remain in the collar. This sling should only be used in conjunction with properly written instructions and with personnel trained in the proper use of the sling.

(18) Flight test verification work that thoroughly checks out the operational envelope should be accomplished with every device approved for external cargo carriage (especially rotorcraft load combination D which includes external human cargo). The flight test program should show that all aspects of the applied for operations are safe, uncomplicated and can be conducted by an average flight crew under the most critical service environment and, in the case of human external cargo, under the pressures of an emergency scenario.

AC 29.865A. § 29.865 (Amendment 29-30) EXTERNAL LOAD ATTACHING MEANS.

a. Explanation. Amendment 29-30 added two requirements to § 29.865:

(1) Section 29.865(a) is clarified to allow use of a design factor less than 2.5g’s, for rotorcraft load combinations A, B, and C non-human external cargo applications provided the lower load factor is not likely to be exceeded by virtue of the

rotorcraft characteristics and capability. That is the rotorcraft design factors may be used for the cargo device system.

(2) Section 29.865(d) was added to clarify and specify the fatigue requirements for the external cargo attaching means. The “rotorcraft” standard is contained in § 29.571, paragraph AC 29.571.

b. Procedures.

(1) For § 29.865(a), if a design limit load factor less than 2.5g’s is requested, the applicant should provide a rational analysis and/or a flight operations data base that clearly shows that the load factor requested is unlikely to be exceeded in service.

Note: § 29.337(b) requires use of 2.0 g’s as a minimum.

(2) For § 29.865(d), all failures of the cargo attaching means (and the associated critical components) that are likely to be hazardous to the rotorcraft should be identified by an acceptable means such as an FMEA. The critical components associated with these failure modes should then be analyzed and/or tested to ensure that the likelihood of a fatigue failure or occurrence is acceptably minimized. In the majority of cases an analysis using the methods of AC 20-95, “Fatigue Evaluation of Rotorcraft Structure”, will be sufficient. Any component’s airworthiness limitations and/or mandatory inspections should be identified by this analysis, approved, and placed in the airworthiness limitations section of the maintenance manual or Instructions for Continued Airworthiness. See paragraph AC 29.1529 (§ 29.1529) for information on these manuals.

FIGURE AC 29.865-1
SUMMARY OF PART 133 ROTORCRAFT LOAD COMBINATIONS CERTIFIABLE UNDER § 29.865
CLASS A

Basic Definition and Intended Use

Fixed External Cargo Container
Is defined by § 1.1 as a load combination in which the external load cannot move freely, cannot be jettisoned, and does not extend below the landing gear. This category usually features multiple attachments (loadpaths) to the airframe. Typical example is a hard mounted cargo basket attached to the rotorcraft crosstubes which is used to carry cargo from point A to point B.

Typical Load Limits

Certification limit is N_{ZW} X Maximum Substantiable External load. N_{ZW} is 2.5 per § 29.865 (See Procedure, paragraph (2)).

Quick Release Requirements

None. Cargo and its container are not jettisonable.

Certification Requirements -- Considerations

- For cargo only.
- Flight Manual Restrictions - § 133.47 requires a rotorcraft load combination flight manual supplement. Any flight envelope restrictions from § 29.865 should be a part of this supplement.
- Load limit placards are required by § 29.865(c).
- Flight envelope restriction placards may also be required for gross weight limitations, e.g., limitations, elimination of dangerous maneuvers, etc.
- Cargo tiedowns to prevent load shifting relative to airframe may be required.
- Effect of external cargo carrier and its maximum cargo weight on load paths, loads and fatigue of existing structure should be determined.
- TIA testing may be necessary to determine whether or not the system performs as intended and if placards and flight manual supplements are adequate.
- The applicant may elect to test the aerodynamic effect of several representative load shapes and include applicable information in the flight manual supplement. If such information is not in the RFM, then the operator may be required to obtain an operations approval under Part 133.

FIGURE AC 29.865-1 (continued)
SUMMARY OF PART 133 ROTORCRAFT LOAD COMBINATIONS CERTIFIABLE UNDER § 29.865
CLASS B

Basic Definition and Intended Use

Single Point Suspension External Load Airborne
Is defined by § 1.1 as a load combination in which the external load is jettisonable and is lifted free of land or water during the rotorcraft operation. The payload is typically suspended from a hook or a similar device. The hook may be attached to the rotorcraft structure or it may be attached to a movable hoist cable and the hoist itself attached to the rotorcraft. Typical use is to lift a cargo load until it is completely airborne and fly it from point A to point B. The load on the hoist may be stowed in the fuselage (in some cases) while being transported.

Typical Load Limits

Certification limit load is N_{ZW} X Maximum Substantiable External load. N_{ZW} is 2.5 per § 29.865 (See Procedure, paragraph (2)). Load may be limited by hoist allowables (reference paragraph (3)).

Quick Release Requirements

§ 29.865(b)(1) requires that a primary quick release system control device be installed on a primary control. Also, a manual quick release system backup actuation device must be available and readily accessible.

Certification Requirements -- Considerations

- For cargo only.
- Flight Manual Restrictions - § 133.47 requires a rotorcraft load combination flight manual supplement. Any flight envelope restrictions from § 29.865 should be a part of this supplement.
- Load limit placards are required by § 29.865(c).
- Flight envelope restriction placards may also be required.
- Certifiable external cargo load capacity may be further limited by §§ 133.41 and 133.43
- Quick release devices must be approved and be operable on a nonhazard basis by the pilot per § 29.865(b).
- Manual backup must be reliable but need not be overly sophisticated (cable cutters, axes, etc., used by crew members)
- Effect of maximum suspended load and its attachment to rotorcraft structure on load paths, loads and fatigue of existing structure should be determined.
- TIA testing may be necessary to determine whether or not the system performs as intended and if placards and flight manual supplements are adequate.

FIGURE AC 29.865-1 (continued)
SUMMARY OF PART 133 ROTORCRAFT LOAD COMBINATIONS CERTIFIABLE UNDER § 29.865
CLASS C

Basic Definition and Intended Use

Single Point Suspension External Load Partially Airborne
Is defined by § 1.1 as a load combination in which the external load is jettisonable and remains in contact with land or water during the rotorcraft operation. The payload is typically partially suspended by a net or cables from a cargo hook or a similar device. The cargo hook may be attached to the rotorcraft structure or may be attached to a movable hoist cable and the hoist itself attached to the rotorcraft. Typically used for stringing wire or laying cable where the payload is only partially suspended from the ground. (Note: Many applications combine both Category B and C operations because of obvious utility involved.)

Typical Load Limits

Certification limit load is N_{ZW} X Maximum Substantiable External load. N_{ZW} is 2.5 per § 29.865 (See Procedure, paragraph (2)). Load may be limited by hoist allowables (reference paragraph (3)).

Quick Release Requirements

§ 29.865(b)(1) requires that a primary quick release system control device be installed on a primary control. Also, a manual quick release system backup actuation device must be available and readily accessible.

Certification Requirements -- Considerations

- For cargo only.
- Flight Manual Restrictions - § 133.47 requires a rotorcraft load combination flight manual supplement. Any flight envelope restrictions from § 29.865 should be a part of this supplement.
- Load limit placards are required by § 29.865(c).
- Flight envelope restriction placards may also be required.
- Certifiable external cargo load capacity may be further limited by §§ 133.41 and 133.43
- Quick release devices must be approved and be operable on a nonhazard basis by the pilot per § 29.865(b).
- Manual backup must be reliable but need not be overly sophisticated (cable cutters, axes, etc., used by a crewmember)
- Effect of maximum suspended load and its attachment to rotorcraft structure on load paths, loads and fatigue of existing structure should be determined.
- TIA testing may be necessary to determine whether or not the system performs as intended and if placards and flight manual supplements are adequate.

FIGURE AC 29.865-1 (continued)
SUMMARY OF PART 133 ROTORCRAFT LOAD COMBINATIONS CERTIFIABLE UNDER § 29.865
CLASS D

Basic Definition and Intended Use

Single Point Suspension External Airborne Personnel Load
Is defined by § 1.1, as a load combination in which the external load is other than Class A, B, or C and has been specifically approved by the Administrator for that operation. This load combination includes human cargo. For human cargo operations, the payload which typically consists of personnel and their containment device is suspended from a hook or a similar device during all or part of a flight. The hook may be rigidly attached to the rotorcraft or may be attached to a movable hoist cable and the hoist itself rigidly attached to the rotorcraft. Typical use is for transfer of personnel to a ship. Carrying devices may transport one or more persons. Typical carrying devices are vest and straps, baskets, life preservers with straps and attachment devices, cages, or a suspended container.

Typical Load Limits

Certification limit load is N_{ZW} X Maximum Substantiable External load. N_{ZW} varies from 2.5 at max gross weight to 3.5 at minimum gross weight. (See Procedures (2)). Load is usually limited by hoist allowable or by personnel carrying device allowable (See Procedure (2), (3), and (10)).

Quick Release Requirements

Section § 29.865(b) does not currently contain quick release requirements for Class D rotorcraft - load combinations, but § 133.45(e)(4) requires that a primary emergency release system control device (requiring two distinct actions) be installed on a primary control or be installed near a designated crew member's station. Also, a manual quick-release system backup actuation device must be available and readily accessible.

Certification Requirements -- Considerations

- For loads other than Class A, B, or C loads. Is used for external personnel loads.
- § 29.865 has not been revised to reflect this category's requirements (it is currently covered by § 133.45(e)(4) only).
- Unless a public-use rotorcraft is being certified, only transport Category A rotorcraft are eligible to use this load category.
- Transport Category A rotorcraft must be certified for an OEI weight and altitude envelope which becomes the maximum envelope that can be used for Class D operations. This is currently required for a Class D rating by § 133.45(e)(1).
- Personnel lifting devices must be approved separately or as part of the certification project.

FIGURE AC 29.865-1 (continued)
CLASS D (continued)

- Devices must carry personnel internally or secure them safely in a harness or equivalent device.
- Flight Manual Restrictions - § 133.47 requires a rotorcraft load combination flight manual supplement. Any flight envelope restrictions from § 29.865 should be a part of this supplement.
- Load limit placards are required by § 29.865(c).
- Flight envelope restriction placards may also be required.
- Certifiable external load capacity is further limited by §§ 133.41, 133.43 and 133.45(e)(3), the load limit of the personnel carrying device.
- Quick release devices must be approved and be operable on a nonhazard basis by the pilot or a designated crewmember per §§ 133.44(c)(6) and 29.865(b).
- The lifting device must have an emergency release requiring two distinct actions § 133.45(e)(4).
- Manual backup must be accessible and reliable.
- Rotorcraft must be equipped to allow direct intercom among all crewmembers per § 133.45(e)(2). This may affect § 29.865 indirectly if human error or placarding could cause inadvertent load release or retention.
- Effect of maximum suspended load and its attachment to rotorcraft structure on load paths, loads and fatigue of existing structure should be determined.
- TIA testing may be necessary to determine whether or not the system performs as intended and if placards and flight manual supplements are adequate.

AC 29.865B. § 29.865 (Amendment 29-43) EXTERNAL LOAD ATTACHING MEANS.

Advisory material for rotorcraft load combination A, B, C, and D safety requirements (External Loads) for Amendment 29-43 is located in Miscellaneous Guidance (MG) 12 of this AC.

SUBPART D - DESIGN AND CONSTRUCTION

MISCELLANEOUS (DESIGN AND CONSTRUCTION)

AC 29.871. § 29.871 LEVELING MARKS.

a. Explanation. Reference marks are required for leveling the rotorcraft on the ground. These marks are necessary for accurate determination of weight and balance effects, particularly after modifications to the basic rotorcraft.

b. Procedures.

(1) Reference marks are sometimes provided in pairs, one high in the cabin and one low. The plumb weight is suspended from the high mark by an appropriate mechanical attachment, and the lower mark is used to level the rotorcraft by centering the plumb weight. The lower reference mark should be a raised or depressed target symbol and shall be applied to a permanent structural component or permanently attached plate in a readily accessible location. Seat tracks, floors, or door sills which are attached with permanent fasteners are typical locations.

(2) Horizontal reference marks for support of bubble levels may also be used, particularly for smaller rotorcraft.

(3) Proper reference should be made to identify the leveling marks or points on the rotorcraft. Design provisions should be made to ensure these locations are not obscured by equipment, fairings, repair, or rework.

AC 29.873. § 29.873 BALLAST PROVISIONS.

a. Explanation.

(1) This rule requires that ballast provisions prevent inadvertent ballast shifting while in flight or as a result of a landing. Shifting of the ballast may cause a hazardous change in the center of gravity thereby affecting rotorcraft controllability.

(2) Other rules noted here allow removable and fixed ballast and require markings or placards to prevent overloading the ballast installation.

(i) Section 29.29 specifies that the rotorcraft empty weight will include any fixed ballast. Section 29.31 allows the use of removable ballast to comply with the flight requirements. However, ballast may not be adjusted (moved, reduced or increased) in flight.

(ii) Section 29.1541 requires conspicuous and durable markings or placards. Section 29.1557 requires placards stating allowable maximum weight, distributed loading, if necessary, and other appropriate limitations for ballast installation.

(3) Section 29.1583(c) concerns Rotorcraft Flight Manual instructions and information about removable ballast or loading information. The instructions must be included in the operating limitations section of the flight manual to allow ready observance of the limitations.

b. Procedures.

(1) The ballast installation may be substantiated by analysis or by static test. The design ultimate load may be derived from flight, landing, or minor crash conditions load factor specified in the rules. Substantiation by analysis will require use of the fitting factor prescribed by § 29.625 where appropriate. If static tests are to be conducted, a test plan should be prepared, submitted for evaluation and agreed upon prior to the test.

(2) Ballast installations in the aft part of the fuselage and tail boom may be subject to significant landing condition angular inertia load factors as well as the usual linear load factors.

(3) Substantiation methods and procedures acceptable for the airframe substantiation may be used for the ballast installation as well.

(4) Removable ballast will require attention to assure the ballast is secured easily and properly and will remain secured under the appropriate ballast design load factor requirements. The flight manual instructions should be evaluated for compliance with § 29.1583(c) by flight test and airframe personnel.

(5) The installation must be designed and placarded or marked for the maximum allowable ballast load and for other appropriate loading limits. Normally compliance with § 29.1541 is accomplished with a drawing review by airframe personnel along with an EMDO compliance and conformity inspection. An additional compliance inspection by airframe personnel can be conducted if desired.

AC 29.877. § 29.877 ICE PROTECTION.

NOTE: § 29.877 was removed and replaced by § 29.1419 in Amendment 29-21. This material is retained since this is one way to show compliance with § 29.877.

a. Background.

(1) In March 1984, the FAA/AUTHORITY for the first time certificated a rotorcraft for flight into known icing conditions. Several other manufacturers are pursuing designs for icing flight capability with certification planned for 1985 or 1986.

(2) Most rotorcraft icing technology has been developed for military rotorcraft. The only U.S. military rotorcraft equipped and approved for flight into icing conditions is

the UH-60A (Blackhawk). The UH-60A is limited to supercooled cloud conditions where liquid water content (LWC) does not exceed 1.0gm/m^3 and outside air temperature (OAT) is not below -20° C.

(3) Many rotorcraft operators have voiced a high priority on obtaining rotorcraft approved for operation in icing conditions.

(4) The icing characteristics envelope of FAR Part 25, Appendix C, has served as a satisfactory design criteria for fixed-wing operations for two decades. The envelope, as presented, extends to 22,000 feet with possible extents to 30,000 feet but does not present icing severity as a function of altitude. At the time the envelope was derived, it was assumed that all transport category airplanes would operate to at least 22,000 feet. For present state-of-the-art rotorcraft, this assumption is not valid. As such, an altitude limited icing envelope based on the same data used to derive the Part 25, Appendix C, and the Part 29, Appendix C, envelopes is presented as an alternate to the full icing envelope. In addition, a second icing envelope which effectively characterizes supercooled clouds from ground level to 10,000 feet is presented as a second alternative to the Part 29, Appendix C, envelope. The second altitude limited envelope described in reference 386d(2) was derived from recent additional airborne measurements.

b. Explanation.

(1) General.

(i) The discussion in this paragraph pertains generally to certifications to the full icing envelope of Part 29, Appendix C, within the altitude limitations of the rotorcraft or to one of the altitude limited icing envelopes based on a 10,000-foot pressure altitude limit. The actual icing envelope considered may be further restricted based on the actual pressure attitude envelope for which certification is requested. It envisions certification with full ice protection systems (rotor blades, windshields, engine inlets, stabilizer surfaces, etc.). With the exception of pilot controllable variables such as altitude and airspeed, limited certification (either in terms of icing envelope or protection capability) is not envisaged at this time due to the difficulty in forecasting the severity of icing conditions, relating the effects of the forecasted conditions to the type of aircraft, and relating the effects of reported icing among various types of aircraft, particularly between fixed and rotary-wing aircraft. In addition, with a limited protection capability, viable escape options may not be operationally available if limitations are exceeded.

(ii) The discussion in this paragraph, regarding rotor blade ice protection, is oriented primarily toward electrothermal rotor deicing systems, since these have the most widespread acceptance and projected use within the industry. Also, most of the testing and research into rotorcraft ice protection to date has been conducted with this type of system. Research is continuing with other types of systems such as anti-icing fluid systems, and information will be added to address certification of these as necessary. It should also be noted that most of the rotorcraft icing experience accumulated to date has been on rotorcraft with symmetrical airfoil sections. The application of this experience to rotorcraft with asymmetrical airfoils should be carefully evaluated. Limited experience has been gained during development and qualification testing of the Army Blackhawk on asymmetrical airfoil icing characteristics. The most prominent difference appears to be a more rapid degradation of airfoil performance. Rapidity of performance degradation is also dependent upon severity of the icing condition (primarily a function of liquid water content) and ice shape (primarily a function of OAT and median volumetric droplet diameter (MVD)).

(iii) The effects of ice can vary considerably from rotorcraft to rotorcraft. Experience gained for a rotor system with an identical blade profile could provide valuable information but should be used cautiously when applied to another rotorcraft. Assumptions cannot necessarily be made based on icing test results from another rotorcraft. Particular care should be exercised when drawing from fixed-wing icing experience as the widely different and varying conditions seen by the rotor blades make many comparisons with fixed-wing results invalid. Likewise, icing effects on rotor blades vary significantly from those on other parts of the rotorcraft. This is due to changing blade velocity as compared with the constant velocity of the remaining parts.

(2) Reference Material. Prior to commencement of efforts to design and certify a rotorcraft, the references listed in paragraph AC 29.877d should be reviewed. FAA Technical Report ADS-4, Engineering Summary of Airframe Icing Technical Data, December 1963, although somewhat dated, is recommended for basic aircraft icing protection system design information.

(3) Objective. The objective of icing certification is to verify that throughout the approved envelope, the rotorcraft can operate safely in icing conditions expected to be encountered in service (i.e., Appendix C of Part 29 or one of the altitude limited icing envelopes presented herein). This will entail determining that no icing limitations exist or defining what the limitations are, as well as establishing the adequacy of the ice warning means (or system) and the ice protection system. A limiting condition may manifest itself in one of several areas such as handling qualities, performance, autorotation, asymmetric shedding from the rotors, visibility through the windshield, etc. Prior to flight tests in icing conditions, sufficient analyses should have been conducted to determine the design points for the particular item of the rotorcraft being analyzed (windshield, engine inlet, rotor blades, etc.). After the analyses are reviewed and found adequate, tests should be conducted to confirm that the analyses are valid and that the rotorcraft can operate safely in any supercooled cloud icing condition defined by Part 29, Appendix C, or one of the altitude limited icing envelopes. References 386d(1) and (3) may be useful in determining the design points and extrapolation of test data to the desired design points.

(4) Planning. For best utilization of both the applicant's and the FAA/AUTHORITY's resources, the applicant should submit a certification plan at the start of the design and development effort. The certification plan should describe all

efforts intended to lead to certification and should include the following basic information:

Rotorcraft and systems description.
Ice protection systems description.
Certification checklist.
Description of analyses or tests planned to demonstrate compliance.
Projected schedules of design, analyses, testing, and reporting efforts.
Methods of test - artificial vs. natural.
Methods of control of variables.
Data acquisition instrumentation.
Data reduction procedures.

(5) Environment.

(i) Definitions.

(A) Supercooled Clouds. Clouds containing water droplets (below 32° F) that have remained in the liquid state. Supercooled water droplets will freeze upon impact with another object. Water droplets have been observed in the liquid state at ambient temperatures as low as -60° F. The rate of ice accretion on an aircraft component is dependent upon many factors such as droplet size, cloud liquid water content, ambient temperature, and component size, shape, and velocity.

(B) Ice Crystal Clouds. Glaciated clouds existing usually at very cold temperatures where moisture has frozen to the solid or crystal state.

(C) Mixed Conditions. Partially glaciated clouds at ambient temperatures below 32° F containing a mixture of ice crystals and supercooled water droplets.

(D) Freezing Rain and Freezing Drizzle. Precipitation existing within clouds or below clouds at ambient temperatures below 32° F where rain droplets remain in the supercooled liquid state.

(E) Sleet. Precipitation of transparent or translucent pellets of ice which have a diameter of 5mm or less.

(F) Hail. Solid precipitation in the form of balls or pieces of ice (hail stones) with diameters ranging from 5mm to more than 50mm.

(ii) Appendix C of Part 29 defines the supercooled cloud environment necessary for certification of rotorcraft in icing except that the pressure altitude limitation is that of the rotorcraft or that selected by the applicant, provided the remaining altitude envelope is operationally practical. Due to air traffic system compatibility constraints, approval of a maximum altitude less than 10,000 feet pressure altitude should be discouraged. However, there are operations where a lower maximum altitude has no effect on the air traffic system and would still be operationally useful. Figures 3 and 6 of Appendix C, Part 29, relate the variation of average LWC as a function of cloud horizontal extent. These relationships should be used for design assessment of the most critical combinations of conditions as a function of en route distance. This, in combination with a capability to hold in icing conditions for 30 minutes at the destination, is commensurate with policies previously established for fixed-wing aircraft. Figures 3 and 6 should be used in conjunction with the altitude limited criteria of figures AC 29.877-1 through AC 29.877-4 herein. The new criteria of figure AC 29.877-5 includes “duration” (horizontal extent) as the third dimension. It is emphasized that LWC extremes expressed in Part 29, Appendix C, criteria and the alternate envelopes represent the maximum average values to be anticipated within an exceedance probability of 99.9 percent. Transient, instantaneous peak values of much higher LWC have been observed. These instantaneous peak values appear to be of little significance to the design of protected and unprotected surfaces; however, these high values, if encountered, may induce shedding of ice from some unprotected surfaces. This is due to radical changes in the rate of release of latent heat and resultant changes in the structural properties and adhesion force of ice.

(iii) A recent analysis performed at the FAA Technical Center concludes that the aircraft icing environment below 10,000 feet is not as severe in terms of LWC and OAT as that depicted in Part 29, Appendix C, envelope. This AC presents two different altitude limited envelopes that may be employed by those applicants who elect to certify with a 10,000-foot pressure altitude limit. One of these altitude limited envelopes is based upon the same data that were used to derive the design criteria of the Part 29, Appendix C (figures AC 29.877-1 thru 4), while the other is based upon a recently established characterization of supercool clouds below 10,000 feet (figure AC 29.877-5). The applicant may select either of the approaches to altitude limitation. At the present time, applicants have not consistently selected one or the other. If experience shows a unanimous preference for one or the other, the one not used will be deleted in a future revision. The data used to derive these limited envelopes cannot be used to further define icing conditions between 10,000 feet and 22,000 feet; hence, above 10,000 feet, the Part 29, Appendix C, envelopes should be used. It should be noted that the engine inlets should still meet the icing requirements of § 29.1093. The limited icing envelopes may be used on an equivalent safety basis to show compliance with the intent of § 29.1093 if the altitude limit established for the rotorcraft is not greater than 10,000 feet.

(iv) Significant effects can result from various combinations of parameters. For example, most rapid ice accumulations occur at the high values of liquid water content, and the greatest impingement area occurs at the high values of droplet size. Most critical ice shapes are a function of each of these parameters in addition to airspeed, surface temperature, and surface contour. Care should be taken to explore the entire specified ranges of these parameters during the design, development, and certification efforts.

(v) Mixed conditions (i.e., a combination of ice crystals and supercooled water droplets) and freezing rain or freezing drizzle are not addressed in the Part 29 environmental criteria but can present more severe icing conditions than those defined. Although the probability of encountering freezing rain is relatively low, mixed conditions commonly occur in supercooled cloud formations. Little data have been gathered on the effects of encountering mixed conditions (see reference AC 29.877d(7)). There are no criteria for certification in mixed conditions or freezing rain at present. In addition to the hazards of operating any aircraft in icing, certain aspects of rotorcraft icing (relatively low altitude operation, asymmetric shedding with resulting vibration, and ice damage or ingestion) warrant a caution notice in the RFM advising that the rotorcraft is not certified for operation in freezing rain or freezing drizzle. Avoidance procedures (e.g., climb or descent) may also be useful.

(6) <u>Flight Test Prerequisites</u>.

(i) The prototype rotorcraft should be capable of IFR and IMC flight.

(ii) Sufficient analyses should be developed, submitted, and accepted by FAA/AUTHORITY to show that the rotorcraft is capable of safely operating to the selected design points of both the continuous maximum and intermittent maximum conditions of Part 29, Appendix C, or one of the altitude limited icing envelopes. A detailed failure modes and effects analysis (FMEA) should be performed.

(iii) Specific attention should be given to (1) assuring that the selected design condition(s) of atmospheric and rotorcraft flight envelopes have been identified; (2) qualification and design of ice protection systems and components; and (3) component installation and ice formation effects upon basic rotorcraft structural properties and handling qualities. These assurances can be established from analyses, bench test, and/or dry air flight tests or simulated icing tests, as appropriate prior to flight tests in natural icing.

(iv) The applicant should assess rotor blade stability with ice deposits to assure that dynamic instability will not occur in icing conditions. This assessment may be accomplished by analysis including consideration of failure of the most critical segment of the rotor blade ice protection system. It also may be accomplished by experimental means such as attaching dummy ice shapes to the blades and using a whirl stand or wind tunnel.

c. <u>Procedures</u>.

(1) <u>Compliance</u>.

(i) In general, compliance can be established when there is reasonable assurance that while operating in the specified icing environment (1) the engine(s) will not flameout or experience significant power losses or damage; (2) stress levels are not reached with ice accumulations that can endanger the rotorcraft or cause serious reductions in component life; (3) the handling qualities, performance, visibility, and systems operation are defined and are not deteriorated unacceptably; (4) inlet, vent or drain blockage (such as fuel vent, engine, or transmission cooler) is not excessive; and (5) autorotation characteristics are acceptable with maximum ice accretion between de-ice cycles. Assessment of performance loss should include not only the drag and weight of the ice itself but electrical or other load demands of the ice protection system and any performance changes resulting from modified rotor blade contours.

(ii) It is emphasized that ice formations (shape, weight, etc.) vary significantly under varying conditions of outside air temperature (OAT), liquid water content (LWC), median volume diameter (MVD), airspeed, attitude, and rotor RPM. The most critical conditions should be defined by means of analyses or test and verified by test. Performance changes under these various conditions should be determined and found acceptable.

(iii) Laboratory, icing tunnel, ground spray rig, and airborne icing tanker tests are all very useful in developing an ice protection capability, but none of these, either individually or collectively, can satisfy the full requirements for certification. None can presently duplicate the combinations of liquid water content, droplet size, flow field, and random shedding patterns found in natural icing conditions. Airborne tankers hold considerable promise of being able to fulfill certification requirements (in addition to the advantage of being able to produce an icing environment on demand rather than having to wait for it to occur in nature), but tankers have not been able to generate droplet sizes that cover the complete envelope for certification. Many improvements have been made in some tankers in recent years; however, large droplet sizes have typically been a problem. Also, the size of existing tanker clouds is not of sufficient cross section to immerse the entire rotorcraft. There are also solar radiation and relative humidity effects to be considered and correlated with natural icing when using a tanker. The tanker should be able to immerse the entire rotor system as a minimum and should have a means of controlling and changing the cloud characteristics uniformly and repeatably. Until an artificial method has been successfully demonstrated and accepted, icing certification should include flight tests in natural icing conditions.

(iv) Flight testing in natural icing conditions also has limitations. Reference AC 29.877d(16) contains information that may be useful in planning natural icing flight tests. The key limitation of natural icing flight tests is being able to find the combinations of conditions that comprise critical design points. This is especially true of those points falling near the 99.9 percentile of exceedence probability; e.g., high LWC at low OAT with large MVD. It is emphasized that some more severe design points, however, may exist within the atmospheric icing envelope rather than near the edges or corners of the envelope. This does not mean that natural icing tests must be conducted at all the selected design conditions. Natural icing tests should be conducted in conditions as close to design points as possible and sufficient correlation shown with the analyses to assure that the rotorcraft can operate safely throughout the design envelope.

(v) Certification flight testing should be extensive enough to provide reasonable assurance that either induced or random ice shedding does not present a problem. The most likely indication of a problem if it exists will be ice impact on the airframe or rotor imbalance resulting in vibration. The following should be considered sufficient for rejection:

(A) Vibrations sufficient to make the instruments difficult to read accurately.

(B) Vibrations sufficient to exceed the structural or fatigue limits of any rotorcraft part such as blade, mast, or transmission components.

(C) Ice impact damage to essential parts, such as the tail rotor, that could create a flight hazard. Cosmetic, nonstructure flaws that do not exceed wear and tear characteristics or maintenance criteria are acceptable. Any ice shedding effects that require immediate maintenance action are unacceptable.

(vi) There should be a means identified or provided for determining the formation of ice on critical parts of the rotorcraft which can be met by a reliable and safe natural warning or an ice detection system. A system utilizing OAT must include an accurate OAT measurement since the onset of icing can occur in a very narrow temperature band requiring sensitive and accurate OAT measurement. OAT accuracy should be relative to the true temperature of the air mass. Total system accuracy should be ±0.5° C in the -5.0° to +5.0° C range and ±1° C throughout the remaining temperature range. The location of the sensor has been shown to be very critical and, in effect, there can be a position error or other errors induced by ice formations or solar radiation. If the system measures liquid water content, consideration should be given to the fact that the actual LWC fluctuates considerably as the rotorcraft passes through an icing environment. A warning system displaying or utilizing a peak or average LWC value (rather than an instantaneous readout) should include sufficient conservatism to provide a margin of safety. The value of an LWC detecting system lies in its utility as a warning that ice is being encountered. The actual magnitude of LWC in combination with OAT and MVD can be used to indicate the icing severity level. The U.S. Army is currently developing an advanced ice detection system for potential application to rotorcraft.

(2) Instrumentation and Data Collection.

(i) Instrumentation proposed for certification tests, including flight strain surveys, should be reviewed as early as possible in the program to establish that it will provide the necessary data. The need for accurate OAT measurement previously noted for operation in icing also applies to the certificated configuration. Mechanical devices such as the rotating multicylinder and rotating disc have been used for measuring ice accretion rate which is relatable by calibration to average LWC and MVD. More recently, hybrid mechanical/electronic LWC measuring devices have been used. Devices that rely on ice accretion as a signal source are subject to the Ludlam limit (the limits whereby latent heat of fusion is not totally absorbed, thus resulting in incomplete freezing of the moisture and some inaccuracy in the indication). The Ludlam limit is a function of various parameters including OAT, airspeed, LWC, and MVD. The Ludlam limit may vary from one device to another. (See references AC 29.877d(8) and AC 29.877d(9)(i) for further information). Gelatin slides, soot and oil slides, and more recently, laser nephelometers, have been used to measure droplet size. Other calibrated devices intended for measurement of LWC should be used. Reference AC 29.877d(16) describes several of these devices. Photographic coverage of critical areas may be necessary to ascertain that ice protection systems are functioning properly and that there are no runback problems. (The term “runback” refers to liquid water that has not been evaporated by surface de-ice equipment and flows back to an unheated area subject to freezing.) Reference AC 29.877d(19) highlights use of video techniques and equipment for this purpose. Some systems will require acceptable calibration techniques and data.

(ii) Gelatin, soot, and oil slides provide data that can be used to estimate MVD at discrete intervals while laser nephelometer data can provide time histories of MVD droplet size distributions. Gelatin slide data should be taken frequently during test flights to properly characterize the cloud. Laser nephelometer data have been found to be highly dependent upon knowledge of the equipment and calibration. Proper calibration, maintenance, and data processing techniques should be utilized and demonstrated. Additional information on the subject may be found in Reference AC 29.877d(18).

(iii) Structural instrumentation requirements should also be established as early as possible in the program. Flight strain measurements are strongly recommended in assessing the ice imposed stress on the rotorcraft. The flight strain measurements should determine the effect on fatigue life due to ice accumulation for such items as main rotor blades, main rotor hub components, rotating and fixed controls, horizontal stabilizer, tail rotor, etc. The subsequent proper operation of retractable devices such as landing gear should be demonstrated with representative ice accretion. In addition, the static and fatigue strength of the blade with heater mat must be substantiated. Any effect of the heater mat on fatigue strength of the blades must be considered.

(3) Additional Considerations. The following are items to consider in an icing certification program. They are not intended to be all-inclusive, and the possibility of widely differing characteristics and critical areas among various rotorcraft in icing should be considered.

(i) The rotorcraft should be shown by analysis and confirmed by either simulated or natural icing tests to be capable of holding for 30 minutes in the design conditions of the continuous maximum icing envelope at the most critical weight, CG, and altitude with a fully functional ice protection system. For those applicants who elect to certify their rotorcraft to the new supercooled cloud characterization of figure AC 29.877-5, the rotorcraft should be shown by analysis and confirmed by either simulated or natural icing tests to be capable of holding for 30 minutes in the design conditions of the icing envelopes up to a maximum of 0.8 grams per cubic meter of LWC at the most critical weight, CG, and altitude.

(ii) A single ice protection system and power source may be considered acceptable provided that after any single failure of the ice protection system, the rotorcraft can be shown by analysis and/or test to be capable of safe operation (no hazard) for 15 minutes following failure recognition in the continuous icing envelope used as the basis for certification within the same icing limits used for the 30-minute hold criteria. During this 15-minute period the rotorcraft may exhibit degraded characteristics. Pilot controllable operating limitations such as airspeed may be used to satisfy this continued safe flight criteria. For purposes of determining performance and handling qualities degradation, ice protection system failure need not be considered to occur simultaneously with engine failure unless ice protection system operation is dependent upon engine operation.

(iii) Although current airborne weather radar technology systems may be useful in avoiding potential icing conditions by detecting precipitation, the use of weather radar is not an FAA/AUTHORITY requirement for icing certification.

(iv) If the ice protection is not operating continuously, there must be a means to advise the crew when the rotorcraft is in icing conditions in order that the system may be activated.

(v) No autorotational performance data is required for rotorcraft which have Category A powerplant installations. All rotorcraft certified for flight in icing conditions must be capable of full autorotational landings with the ice protection system operating. Autorotational entry, steady state, and flare entry flying qualities and performance should be evaluated with an ice load. Since the Category A en route performance can vary as the ice protection system operates, a mean value of cyclic torque is acceptable provided at no time does the rate of climb fall below zero. The rotorcraft is assumed to be clear prior to takeoff, and therefore the takeoff performance is not degraded. The landing performance can be based on the in-flight assessment of overall performance degradation. Items such as fuel burns can be used as part of the in-flight performance degradation determination. Regardless of the methods used to determine performance degradation, it must be easily used by the crew. The hover performance should be addressed for the termination of a flight after an icing encounter. The engines must be protected from the adverse effects of ice. When ice does accumulate on the inlets, screens, etc., it must be accounted for in performance, engine operating characteristics, and inlet distortion.

(vi) The handling qualities of the rotorcraft must be substantiated if ice can accumulate on any surface. When ice can accumulate on unprotected surfaces the rotorcraft must exhibit satisfactory VFR/IFR handling qualities. In addition, following the failure of the de-ice system, the rotorcraft must be safely controllable for 15 minutes, i.e., the rotorcraft must be free from excessive and rapid divergence.

Artificial ice shapes may be acceptable for acquisition of flight test data necessary for handling qualities and performance evaluations and demonstrations.

(vii) Items such as fuel tank vents, cooling vents, antennas, etc., must be substantiated for maximum icing effects.

(viii) The ice protection system should be sufficiently reliable to perform its intended function in accordance with the requirements of § 29.1309. These requirements may in some instances be met by the use of sound engineering judgment during design and compliance demonstrations. In many instances, use of good design practices, failure modes and effects analysis, and similarity analyses combined with good judgment will be adequate. In some instances the need for reliability analyses may be desirable. Additional information pertaining to reliability is contained in paragraph AC 29.1309 (§ 29.1309).

(ix) The subject of lightning must be addressed. The criteria applied on rotorcraft with ice protection systems are that "the rotorcraft must be protected in such a manner to minimize lightning risk." The general rules of § 29.1309(a), (b), and (c) are applicable to assure adequate lightning protection.

(x) Ice protection of pitot-static sources, windshields, inlets, exposed control linkages, etc., must be considered.

(xi) The impact of ice protection system failure, complete and partial, and achieving adequate warning thereof must be assessed.

(xii) The impact of delayed application of ice protection systems should be assessed. Hazardous conditions should not be apparent. Any rotorcraft characteristic changes resulting should be covered in cautionary material in the rotorcraft flight manual.

(xiii) Possible droop stop malfunction with ice accumulation and its potential hazard to the rotorcraft, its occupants, and ground personnel must be assessed.

(xiv) Possible ice shedding hazards to ground personnel or equipment in proximity to turning rotors following flight in icing conditions should be given much consideration.

(4) Flight Manual. Areas of the flight manual which may require inputs are:

(i) Operating limitations including approved types of operation and prohibiting operation in freezing rain or freezing drizzle conditions. Avoidance procedures may also be useful.

(ii) Normal Operating Procedures. Information on the ice detection means or system and ice protection system and its capabilities.

(iii) Emergency Operating Procedures. Operating procedures containing essential information particularly with system failure.

(iv) Caution Notes. These caution notes should advise or address:

(A) Against inducing asymmetric shedding with rapid control inputs or rotor speed changes, except possibly as a last resort. Rotor speed changes appear to be more effective than control inputs in removing ice from the rotor blades of some rotorcraft.

(B) Loss in range, climb rate, and hover capability following prolonged operation in icing.

(C) The need for clean blade surfaces and use of approved cleaning solvents or ground deicing/anti-icing agents prior to starting rotors.

(D) Changes in autorotational characteristics resulting from formations.

(E) If the rotorcraft has been certificated for flight in supercooled clouds and falling and blowing snow, flight in other conditions such as freezing rain, freezing drizzle, sleet, hail, and combinations of these conditions with supercooled clouds should be avoided.

(F) The potential hazards to ground personnel, passengers deplaning, and equipment in proximity to turning rotors following flight in icing conditions.

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(xiv) Limited Artificial and Natural Icing Tests, Production UH-60A Helicopter (Reevaluation), Final Report, August 1981, USAAEFA Project No. 80-14.

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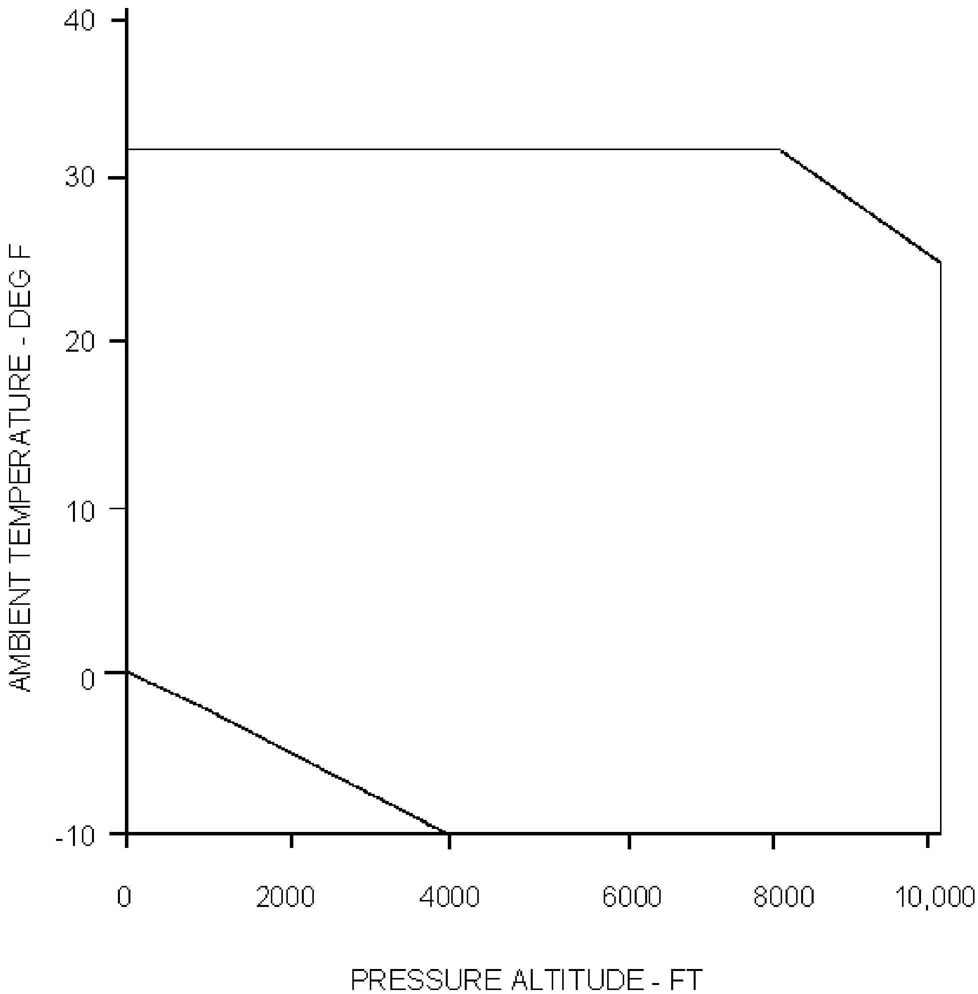

FIGURE AC 29.877-1 CONTINUOUS ICING - TEMPERATURE VS ALTITUDE LIMITS

Figures AC 29.877-1 through 4 represent one approach to a 10,000-foot altitude limit and Figure AC 29.877-5 represent another. See Paragraph 386b(5)(iii) for a discussion of the individual application of the two approaches.

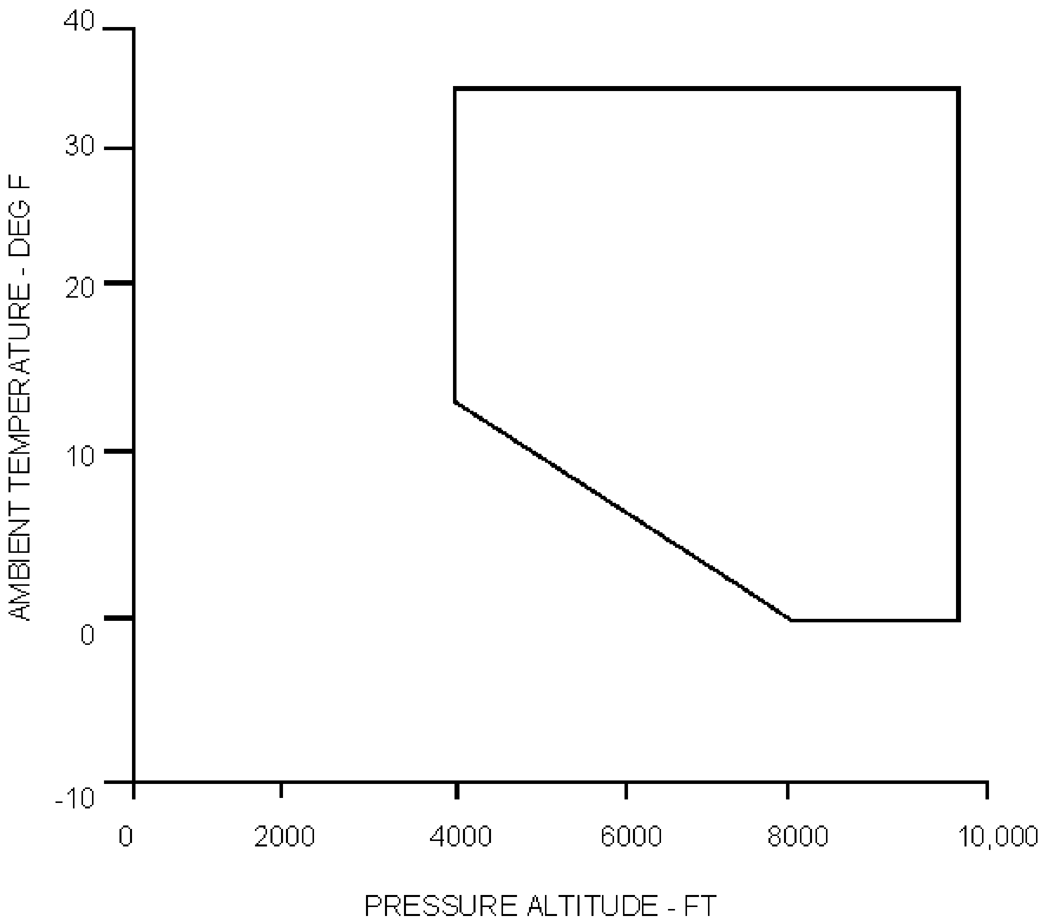

FIGURE AC 29.877-2 INTERMITTENT ICING - TEMPERATURE VS ALTITUDE LIMITS

Figures AC 29.877-1 through 4 represent one approach to a 10,000-foot altitude limit and Figure AC 29.877-5 represents another. See Paragraph 386b(5)(iii) for a discussion of the individual application of the two approaches

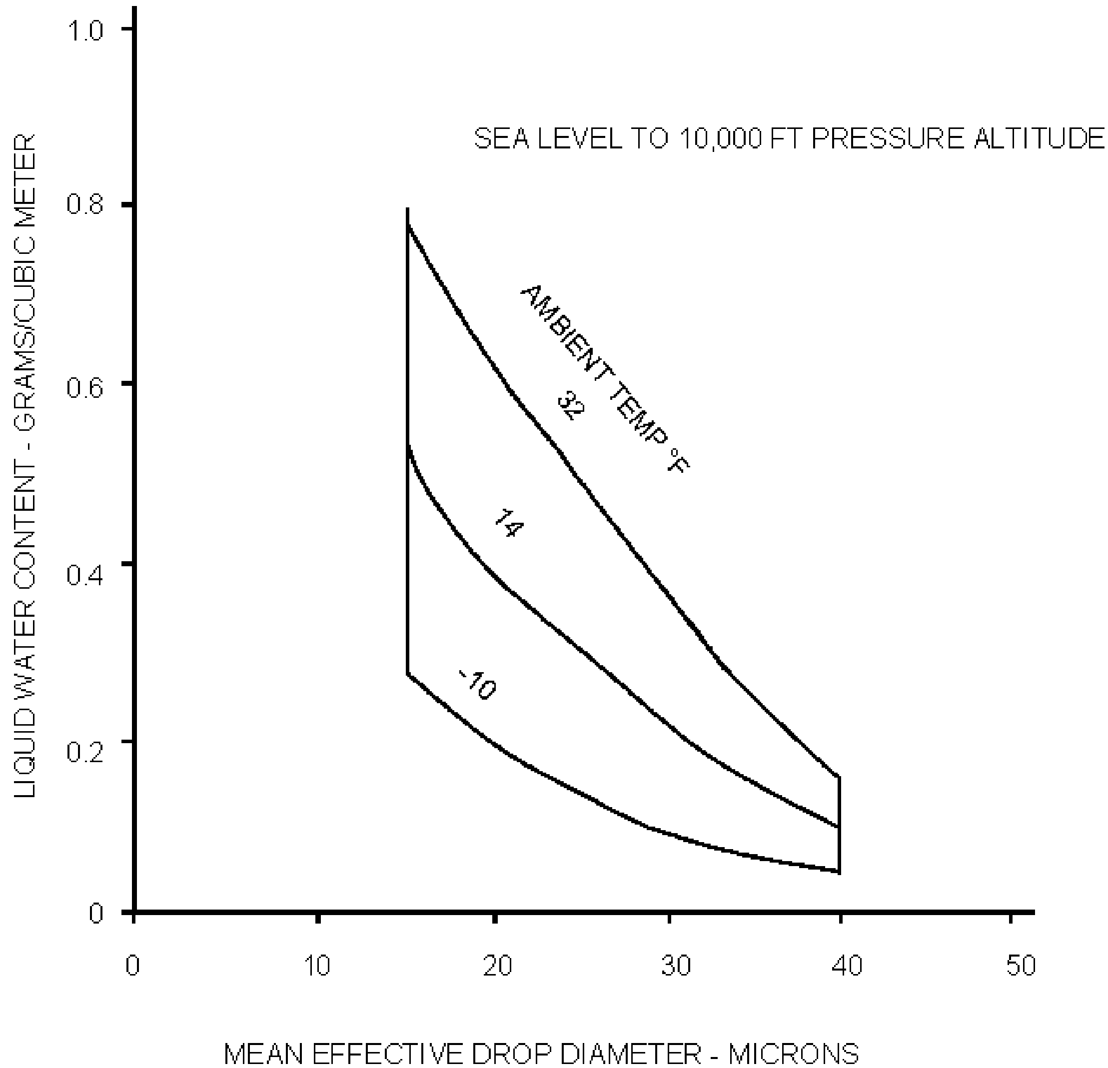

FIGURE AC 29.877-3 MEAN EFFECTIVE DROP DIAMETER - MICRONS

Figures AC 29.877-1 through 4 represent one approach to a 10,000-foot altitude limit and Figure AC 29.877-5 represents another. See Paragraph 386b(5)(iii) for discussion of the individual application of the two approaches.

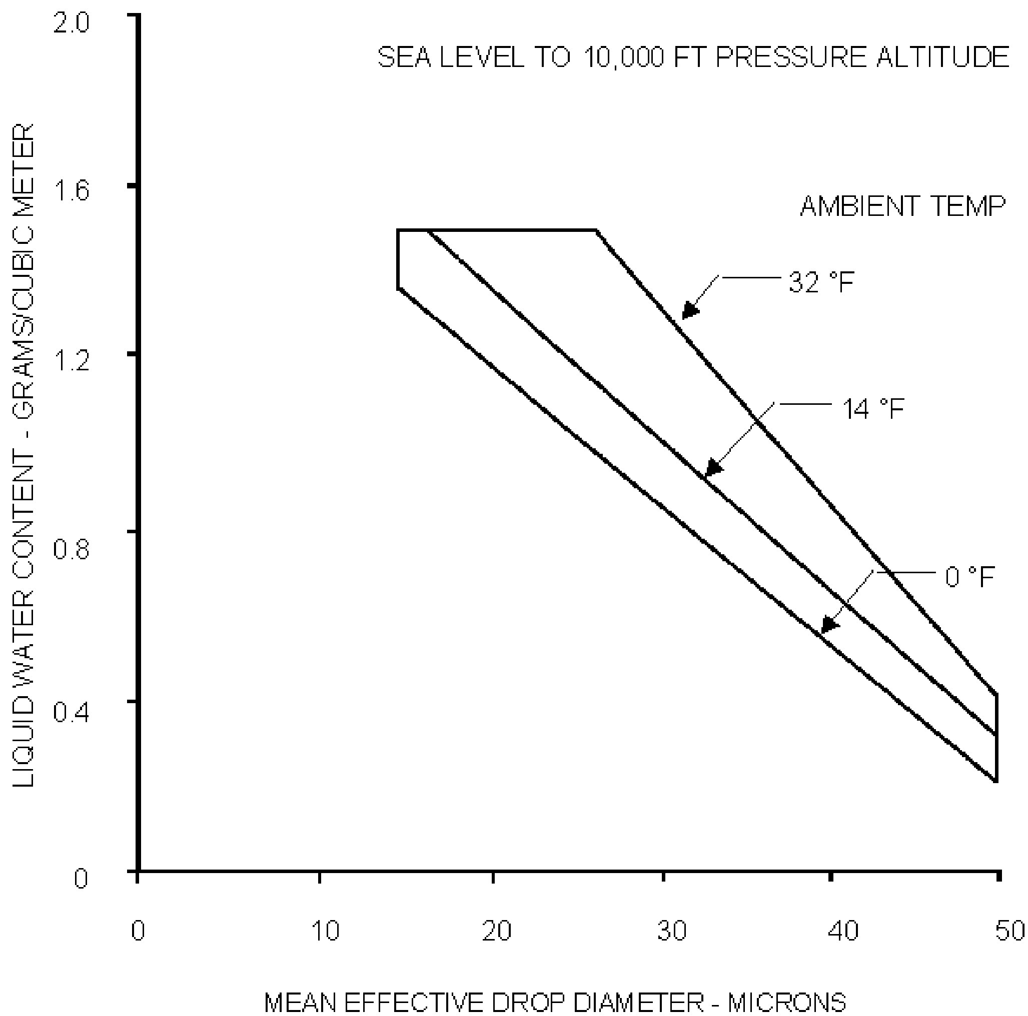

FIGURE AC 29.877-4 INTERMITTENT ICING - LIQUID WATER CONTENT VS DROP DIAMETER

Figures AC 29.877-1 through 4 represent one approach to a 10,000-foot altitude limit and Figure AC 29.877-5 represents another. See Paragraph 386b(5)(iii) for a discussion of the individual application of the two approaches.

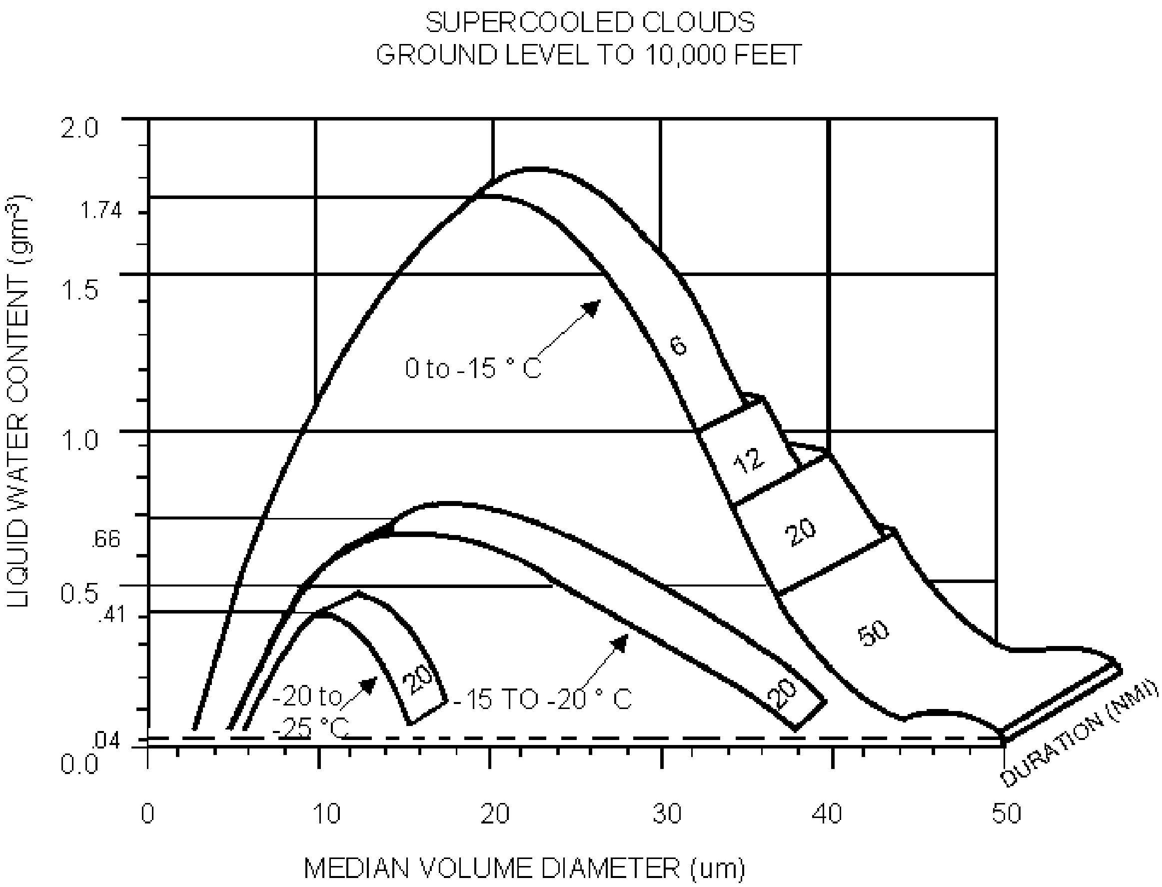

FIGURE AC 29.877-5

Figures AC 29.877-1 through 4 represent one approach to a 10,000-foot altitude limit and Figure AC 29.877-5 represents another. See Paragraph 386b(5)(iii) for discussion of the individual application of the two approaches.